NIAGARA FALLS

Westerly portion of Canadian Falls

The Hydro-Electric Power Commission of Ontario

Its Origin Administration and Achievements

TORONTO ~ ONTARIO
1928

THE HYDRO-ELECTRIC POWER COMMISSION

OF ONTARIO

CHARLES A. MAGRATH.....*Chairman*

HON. J. R. COOKE, M.L.A.....*Commissioner*

C. ALFRED MAGUIRE.....*Commissioner*

W. W. POPE.....*Secretary*

F. A. GABY, B.A.SC., D.SC.....*Chief Engineer*

CONTENTS

ILLUSTRATIONS

THE

HYDRO-ELECTRIC POWER COMMISSION

OF ONTARIO

ITS ORIGIN

ADMINISTRATION AND ACHIEVEMENTS

THE ELECTRICAL undertaking administered by the Hydro-Electric Power Commission of Ontario is a co-operative municipal-ownership enterprise, province-wide in its field, operating through the agency of independent Commission control and administration, and free from so-called political influence. Broadly, the Commission is entrusted with the duty of supplying the electrical needs of the citizens of Ontario municipalities at the lowest possible cost consistent with sound economics. The Commission has now been actually supplying electrical energy since the year 1910. During this period the costs of electricity to the consumer have been substantially reduced and the finances of the enterprise have been established on an increasingly secure foundation. This public-ownership enterprise, administered with efficiency and designed to meet the circumstances existent in the Province of Ontario, is eminently satisfactory, and on behalf of the citizens of the Province renders a service that is unsurpassed in any other comparable territory. The service given by the Commission is popularly referred to as "Hydro" service and throughout the Province the organization is known as "the Hydro,"—terms which apply both to the central organization which provides power wholesale for the municipalities, and to the local municipal authorities which in their respective communities distribute electricity to the individual consumers. In the following pages will be found a brief discussion of basic principles, an historical sketch of the Commission's origin, an outline of its administration, an account of its achievements and, finally, descriptions of the chief developments which supply power throughout the various systems of the Commission.

General Principles

There are certain elements which must lie at the foundation of any movement such as that carried forward by the co-operating municipalities of the Province of Ontario, if such a movement is to succeed. First of all there must be a genuine desire on the part of citizens to have electrical energy, or whatever the commodity may be, supplied to them under such conditions and circumstances as would prevail under public ownership.

It is equally important that the men who undertake to found a publicly-owned enterprise, especially during its initiatory stages, should be responsible and prominent citizens of good business standing and character, who will inspire and hold public confidence. Such men must be willing to make sacrifices on behalf of the new program; for just so soon as it is perceived that matters are being undertaken in a serious and successful manner, opposition will begin to assert itself from various sources. Courage and perseverance are other qualities which are required by those who sponsor public-ownership undertakings.

Again, the necessary financial resources should be supplied by the people who will themselves benefit from the undertaking. Financial resources are required, even for the preliminary researches and investigation of the problem in hand. The investment by citizens of their own money in a local, publicly-owned enterprise, of itself arouses, and assists to maintain, interest.

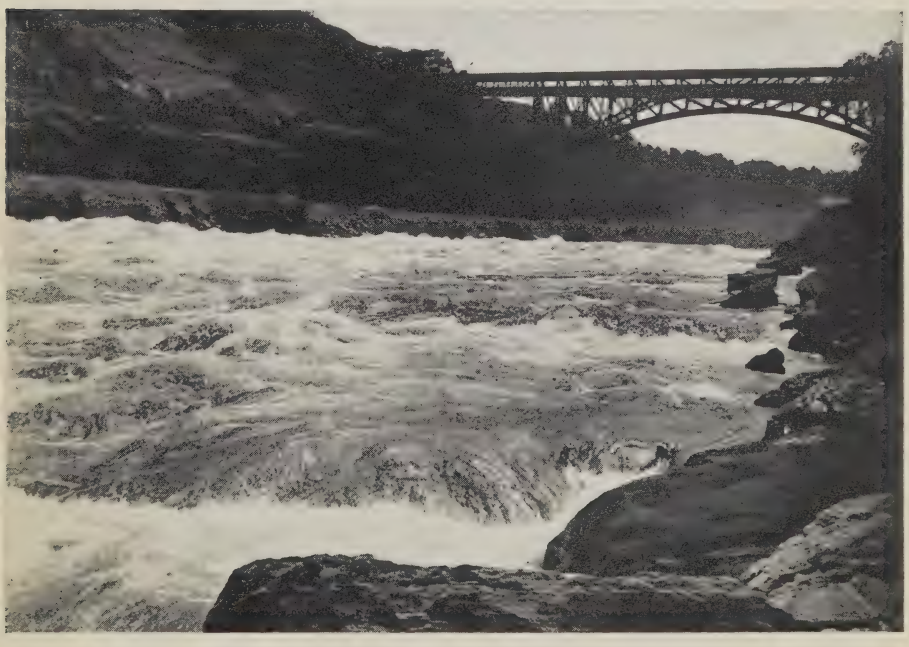
Technical men having thorough engineering, financial and other training must be engaged who will, with singleness of purpose, gather the facts and assist in forming sound judgment, based upon the data secured. Later, their services will be required in guarding, directing and operating the publicly-owned utility. In this connection, continuity of administration is essential, and this can only be achieved by a freedom from political domination in the formulation of policy and in the appointment of officials.

Finally, throughout all the proceedings, the general public must be taken into confidence and kept adequately informed. As opportunity offers, the citizens should be given an understanding of the general character of the various problems under consideration.

In a word, a successful public-ownership enterprise whether it be of schools, of municipal works, of transportation systems, or of electrical utilities, cannot be successfully imposed upon an unwilling community; it must be broad-based upon the people's will. Unless there be a desire on the part of the citizens of a community to proceed on a basis of public ownership; unless there be responsible and qualified public men ready to make sacrifices to achieve the results desired; unless competent technical assistance be employed under conditions which ensure continuity of administration, and unless the people themselves are ready to back the project with their financial resources, no program of public ownership can be expected to be satisfactorily initiated and carried forward on a basis of permanency.

NIAGARA FALLS

General view of American and Canadian Falls as seen from the Upper Arch Bridge. The great amount of power within economic transmission distance of centres of population largely inspired Ontario's municipally-owned electrical undertaking



RAPIDS IN THE NIAGARA GORGE

View looking upstream from the Canadian side

QUEENSTON-CHIPPAWA POWER DEVELOPMENT

Diagrammatic bird's-eye view of the great Queenston-Chippawa power development on the Niagara river, the largest single hydro-electric development in the world. It was constructed by the Hydro-Electric Power Commission of Ontario for the co-operating municipalities of the Province. The view shows intake from Niagara river above the Falls with Welland river section in foreground leading water to control works at upper end of canal which stretches to power house at Queenston where water is returned to the lower Niagara river

From time to time, the Commission has received communications from various sections of this and other continents, requesting information respecting the operations of the Hydro-Electric Power Commission of Ontario. It is evident in many instances that the enquirers entertained a hope that they would receive detailed knowledge of the operations of the municipally-owned hydro-electric undertaking in Ontario in such a form as would enable a similar project to be carried out in their own community. Some appear to forget the fact that each situation requires to be studied on its own merits, and the various essential factors properly evaluated, before a decision can be made as to what particular features of administration shall be adopted. In the case of this Commission changes have had to be made from time to time in statutory enactments, regulations, and other items appertaining to the Commission's administration. A competent staff will soon discern where enactments are inadequate and by means of what modifications they may be made effective.

The above considerations cannot be too strongly emphasized, because it is all-important to realize that certain basic circumstances and certain fundamentals of procedure must obtain if a movement such as that of the Hydro-Electric Power Commission of Ontario is to be initiated with any promise whatsoever of ultimate success.

Keeping these general principles in mind, the Hydro-Electric Power Commission of Ontario will now be described and, as its achievements are set forth, the pertinence of the general comments which have just been made will be apparent.

ORIGIN OF THE ENTERPRISE

At the beginning of this century there were increasing evidences that the central portion of Canada was destined to become an important region for manufacturing industries. The Province of Ontario possesses many natural advantages and compares most favorably with any large territory found elsewhere. Its important natural resources of agricultural areas, forests and minerals supply raw material for extensive and growing industries. It was recognized, therefore, that there were possibilities for an increased export of farm and manufactured products, and that there was no reason why the Province of Ontario—especially with an adequate supply of power—should not take a prominent place in world commerce.

It had become widely recognized that the growing dependence of the Province of Ontario upon outside sources for its fuel supply constituted a handicap which it was greatly desired to lessen or remove, especially in so far as the coal requirements for the production of power were concerned. A number of public-spirited citizens, impressed with the urgent necessity of utilizing the large water-power resources of the Province—more particularly Niagara Falls—as a means of largely eliminating the use of coal for the

generation of power in Ontario, applied themselves to the solution of this problem.

It was in 1900 that a special committee of the Toronto Board of Trade made a report directing attention to the possibilities of securing an abundant supply of hydro-electrical energy from the Niagara river. There were also, at this time, in many of the other municipalities of Ontario, citizens who had recognized the desirability of securing adequate supplies of electrical energy for both power and light at low cost. These citizens were studying the problem and were ready for co-operative action once a suitable scheme was formulated.

Public Interest Leads to Government Action

The interest manifested in the power problem increased and was greatly stimulated by means of public meetings, and by discussion in the press. Appeals for enabling legislation were made to the Provincial Government, and finally, as a result of the general movement on behalf of cheaper hydro-electrical energy, the Government of Ontario, in 1903, provided the means whereby interested municipalities could appoint a commission to investigate and report upon questions involving the supply and distribution of power.

The authority thus granted resulted in the appointment by the municipalities of Toronto, London, Brantford, Stratford, Woodstock, Ingersoll and Guelph, of the Ontario Power Commission, which, after a thorough investigation, published, in 1906, a comprehensive report. In this report, the availability and costs of power from the primary sources of coal, gas, oil and water were set forth, also data respecting the consumption and estimated future requirements of power in the districts concerned, the cost of the development of Niagara power, and other relevant matters.

Creation of the Hydro-Electric Power Commission of Ontario

When the results of this investigation became known to those interested, and even before the report was available for public distribution, the Provincial Government, in 1906, provided by special Act for the creation of the Hydro-Electric Power Commission of Ontario—the organization now in existence. In 1907, further legislation was passed strengthening and extending the powers of the Commission. One essential difference between the Act of 1903 and the later Acts of 1906 and 1907 is that under the 1903 Act various municipalities could combine into separate groups operating through separate commissions, whereas in the later Acts provision is made whereby all municipalities appeal to the Hydro-Electric Power Commission of Ontario and make known their wants. The Commission is thus able to harmonize their various requirements and co-ordinate the municipalities into suitable groups or systems. In 1908, by-laws were passed by thirteen municipalities authorizing their officials to make contracts with the Commission for a supply of electrical power from Niagara Falls.

Commission Contracts for its First Supply of Power

After much study of various proposals for securing the necessary power for distribution to the municipalities, it was concluded best to initiate this municipal enterprise by purchasing power by public tender from existing companies which had extensive plants already erected at Niagara Falls. Consequently, in 1908, the Commission, on behalf of the municipalities, entered into a contract with the Ontario Power Company for the purchase of electrical energy up to a maximum of 100,000 horsepower. The Commission proceeded to build transformer stations and transmission lines for the distribution of this power to the contracting municipalities, to several of which, by the end of 1910, power was being distributed. The initial capital expenditure to serve some twelve municipalities amounted to about $3,600,000.

New Sources of Power Supply Were Soon Required

The twelve original municipalities to which the Commission supplied electrical service in 1910 were rapidly added to until, in 1915, there were 130; in 1920 there were 263; in 1925 the number had reached 436, while in 1928 the Commission is supplying electrical service to about 550 municipalities, of which 325 are urban municipalities—including 25 cities and 84 towns —and 225 are townships.

The small initial load of less than 1,000 horsepower increased rapidly until in 1914 it was 77,000 horsepower, and by 1915 the Commission reached the limit of its contract with the Ontario Power Company for 100,000 horsepower. The Commission then arranged for an additional power supply from the Canadian Niagara Power Company of 50,000 horsepower and from the Toronto Power Company of over 25,000 horsepower. Subsequently, in August, 1917, it purchased outright the Ontario Power Company with its plant capacity of 160,000 horsepower—which was increased to 180,000 horsepower in 1919—and, in December, 1920, acquired the Toronto Power Company, with its plant of over 125,000 horsepower capacity. In 1920 the load was 356,000 horsepower. In view of the rapid increase in loads, legislation was enacted, authorizing the Commission to construct the Queenston-Chippawa development. The first unit of this development was placed in commercial use in January, 1922. In December, 1925, the plant was brought up to its present capacity of about 550,000 horsepower by the installation of the ninth unit. To-day, including power exported under long-term agreements entered into by certain power companies before their acquisition by the Commission, the Hydro-Electric Power Commission is distributing more than 1,000,000 horsepower. The bulk of this power comes from twenty-two water-power plants which the Commission operates. With new plants in process of development and additional power to be supplied under contract, the Commission has now provided for a total power supply of about 1,400,000 horsepower.

Effective Leadership

Many prominent and public-spirited citizens contributed to the establishment of the undertaking and have guided its development. One name, however, stands out preëminently, that of Sir Adam Beck, who for nearly twenty years was the head of the Hydro-Electric Power Commission. When the obtaining of electrical energy from Niagara Falls to serve the needs of Ontario municipalities first became a practical issue, Sir Adam Beck—then Mr. Beck, a prominent manufacturer in London, Ontario—was one of the leading advocates of the project, and upon the creation of the Commission in 1906 was appointed Chairman, a position he held until his death. It may be said that he adopted this great public-ownership undertaking as his life's work, and its outstanding success is in large measure due to his forceful leadership, his constructive ability and zeal, and his administrative capacity. He died on the fifteenth of August, 1925, and the citizens of Ontario pay sincere homage to his life and work.

ADMINISTRATION OF THE UNDERTAKING

The basic conception of the whole municipally-owned, electrical undertaking as administered by the Hydro-Electric Power Commission of Ontario is a partnership of municipalities formed to obtain power at cost, each municipality paying its proportion of the cost for the service received. The Commission, acting as agent and trustee for the municipalities, exercises both administrative and constructional functions, and by application of the principles adopted, has evolved a well-defined and successful working policy for the development, transmission and distribution of hydro-electric power under municipal ownership.

The Hydro-Electric Power Commission of Ontario normally consists of a Chairman and two Commissioners, all of whom are appointed by the Lieutenant-Governor-in-Council of the Province, to hold office during pleasure. At least one of the Commissioners is required to be a minister of the Crown without portfolio, and it has been the practice to appoint one of the Commissioners with special regard to the matter of his familiarity with the aims and wishes of the associated municipalities. The Commission's powers are defined in and controlled by Acts of the Provincial Legislature, known as the Power Commission Act and amendments thereto.

Economic Structure of "Hydro" Undertaking

Certain principles, which the inaugurators of the "Hydro" undertaking believed sound, and which have since proved to be so, were laid as a basis for administering the various assets in which the municipalities are concerned. The general system of administration adopted may briefly be summarized as follows:

First: The generation and transmission of power on a wholesale scale is dealt with by a Commission which, although appointed by the Government

of the Province, acts independently in the capacity of trustee for the partnership of municipalities.

Second: The local distribution of electrical energy within the borders of each municipality is, in general, under the administration of a public utilities commission appointed by the municipality under the provisions of the Public Utilities Act.

Third: Capital required for plant to generate and transmit power is loaned by the Government upon receipt of formal requisition from the Commission. Contracts are executed between the Commission and the municipalities under the terms of which the latter undertake to repay, over a period of forty years, the moneys thus loaned by the Government, with interest in full.

Fourth: The local distribution system is financed by the issue of municipal debentures. Provision is made in the rates charged to the ultimate consumers, for revenue with which to retire these bonds also, in from twenty to thirty years.

Fifth: The Commission supplies power to the municipalities, charging each municipality the actual cost. To do this, an interim charge is made monthly, based upon the estimated cost, and, at the end of each year, credit or debit adjustment is made of the amount charged in order to make up the actual total cost. The "cost of power" includes all the usual costs of operation and maintenance of the generating, transforming and transmission plant and equipment, and, in addition, the annual interest charges on the moneys borrowed for the initial cost of installation, also provisions for renewal (depreciation) and sinking-fund reserves, as well as a special reserve fund for obsolescence and contingencies.

Sixth: Each municipality sells electrical energy to its own local consumers at rates and under conditions approved by the Commission. The rates charged to its consumers by a municipality are made sufficient to take care both of the cost of distribution within the municipality, and of the cost of power to be paid to the Commission by the municipality.

Seventh: Under the Power Commission Act, the Commission is required to determine, annually, the actual cost of service supplied to each municipal corporation by the local commission for such strictly municipal purposes as street lighting, and for the operation of water-works pumps and street railways, and if any profit has accrued through the charging of the rate used throughout the year this surplus is returned to the municipality.

If a municipality desires to obtain a supply of power from the Commission, a vote is taken at the polls and, if the result be favorable, an enabling by-law is passed whereby the municipality is empowered to make a contract with the Commission for the amount of power required. The Commission's engineers are at the service of the municipality to enable a reasonable estimate of the requirements to be made. The contract having been duly executed, a money by-law must then be passed authorizing the Municipal Council to

issue the debentures necessary to cover the cost of constructing a local distribution system within the limits of the municipality; the Commission then proceeds with the building of transmission lines, sub-stations, and other necessary works.

Financial Administration

The whole hydro-electric undertaking of the municipalities, so far as finances are concerned, is administered in what may be termed two distinct divisions. The first division covers the financial obligations incurred in the generation, transformation and transmission of electrical energy in wholesale quantities to municipalities.

The second division comprises the various operations involved in the local distribution by the municipal utility commissions, within their respective municipalities, of the electrical energy which they purchase from the Hydro-Electric Power Commission and sell to the ultimate residential, commercial and industrial consumer.

The ultimate source of all revenue—whether for the large operations of the Hydro-Electric Power Commission or for the smaller local operations of the municipalities—is, of course, the consumer. The revenue collected from consumers for the service supplied by the municipalities is divided so as to pay for the power purchased from the Commission and also for the expense incurred by the local utility in supplying its customers.

The portion of the total revenue remitted to the Hydro-Electric Power Commission is known as the "cost of power" to the local utility and must be sufficient to pay the municipality's portion of the expenditures made by the Commission on its behalf, in connection with the particular system to which it belongs, in order to provide, transmit and sell to the municipality the agreed-upon amount of power. Included in this remittance to the Commission for the cost of power are sums applicable to each of the major divisions of expense involved in the business of providing and transmitting power. It will be informative to explain just what the Commission's administrative practice is with respect to these costs.

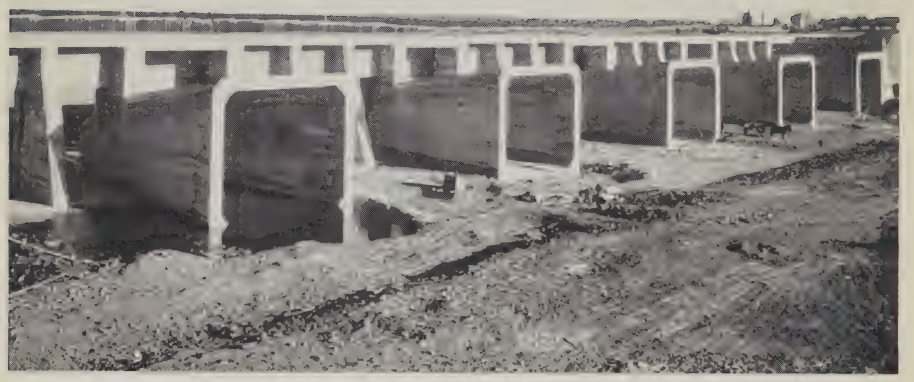
The first item is the cost of power purchased by the Commission from other electrical plants. At the present time, most of the power used in Ontario is generated in the Commission's own plants, and consequently expense for purchased power is relatively small.

The second item is the cost of operating and administering the system, and of maintaining all of its component parts in a state of good repair. Salaries, wages, office expenses, cost of materials, insurance, taxes and water rentals paid to the government, are included under this heading, and account for about 24 per cent of the total.

The largest outlay is for interest on the money invested in the permanent plant. The undertaking is conducted on a strictly commercial basis, and full

QUEENSTON-CHIPPAWA POWER DEVELOPMENT

Completed rock section of power canal with smooth concrete lining, showing the Canadian National and Michigan Central Railway bridge with train; also the Wabash Railway bridge and the Niagara-St. Catharines and Toronto Railway bridge



QUEENSTON-CHIPPAWA POWER DEVELOPMENT

Intake structure, now submerged. The magnitude of the structure will be appreciated by comparing the sizes of men and team near fourth opening

QUEENSTON-CHIPPAWA POWER DEVELOPMENT

Portion of completed power canal as seen from the air, showing approach to Whirlpool gully and continuation to forebay on the top of the cliff at the Niagara river which is seen in the upper part of the picture

interest charges are paid on all money advanced for construction, whether directly by investors, or through securities of the Province. The Government does not even contribute indirectly to the cost of power by authorizing any issue of tax-exempt securities. Interest payments at the present time amount to about 50 per cent of the total, although, as each separate bond issue is retired at the end of the sinking fund period, the consumers will be relieved of the corresponding interest payments.

The renewals reserve is a fund designed to take care of replacing worn-out plant. About six per cent of the cost of power paid by the municipalities is laid aside for this fund.

A second reserve fund, known as the "Reserve for Contingencies and Obsolescence", is made necessary by the improvements in electrical and other apparatus that are constantly being introduced as the result of research and invention. This fund is also available to meet any unforeseen expenses that may arise in the future, and about seven per cent of the charges to the municipalities is contributed each year to this fund.

The two reserve funds mentioned, therefore, provide the means whereby the Commission ensures that the plant employed in the generation and transmission of power will always be renewed as it wears out, and will always provide the cheapest and most reliable power made possible by advances in science and engineering.

The third fund which the Commission accumulates out of the charges for power, and which accounts for the remaining ten per cent of the total, is a sinking fund designed to repay the money from time to time advanced by the Province and by the bond-holders, for purposes of constructing the necessary plant.

In view of the foregoing, it will be recognized that Ontario consumers can look forward to the time when the present plant will be clear of encumbrance, and they will be relieved of the necessity of paying interest and sinking fund thereon, which together amount to sixty per cent of the total expense for generation and transmission.

Now, with respect to the *local* distribution systems, all municipal electric utilities have current expenses to meet, similar to the expenses of the Commission, and have adopted the same sound financial procedure with respect to their operations. In other words, concurrently with the creation of funds to liquidate their debt to the Commission and provide a reserve to rebuild generating, transforming, and transmission systems, the municipalities take similar action with respect to their local "Hydro" systems.

Various "Hydro" Systems were Formed as Circumstances Dictated

Although the "Hydro" undertaking originated with municipalities which could be supplied with power from Niagara Falls, the legislation which created the Commission made it province-wide in its field. It was, of course, not feasible to supply power from a single source, such as Niagara

Falls, to all the municipalities that desired to obtain it through the Commission. From time to time, therefore, when various municipalities or groups of municipalities in districts adjacent to other sources of hydro-electrical energy requested the Hydro-Electric Power Commission to take action on their behalf, separate hydro-electric systems were formed.

In some cases these smaller systems grew until their transmission lines interlocked with those of adjacent systems, and two or more systems became physically one from an operating standpoint. Finally, when this stage was reached it was sometimes proved beneficial to extend the consolidation to include the financial and administrative features—a procedure which has effected substantial economies.

Present Systems Operated by the Commission

The systems at present operated by the Commission, eight in number, are as follows:

The Niagara System—This is the largest and most important system. It embraces all the territory between Niagara Falls, Hamilton and Toronto on the east and Windsor, Sarnia and Goderich on the west, as served with electrical energy generated at the several plants on the Niagara river. These include the plants formerly owned by the Ontario Power Company and the Toronto Power Company, also the great Queenston-Chippawa power development. Additional supplies of power for the Niagara system have been contracted for from developments on the Gatineau river in the Ottawa river watershed. Into the present Niagara system have been absorbed the transmission networks and customers formerly known as, or served by, the Essex County system, the Thorold system, the Ontario Transmission Company and the Toronto and Niagara Power Company.

Georgian Bay System—This system, which is a consolidation of four systems previously existing—the Severn, Eugenia, Wasdells and Muskoka systems—serves that part of the Province of Ontario which surrounds the southern end of Georgian bay and lies to the north of the territory served by the Niagara system. It includes the district surrounding lake Simcoe and extends as far north as Huntsville in the Lake-of-Bays district. It is served by five generating stations—the Wasdells and the Big Chute on the Severn river, the Eugenia on the Beaver river, and the South Falls and Hanna Chutes developments on the Muskoka river. Of these, the Big Chute plant was purchased from the Simcoe Railway and Power Company and subsequently enlarged by the Commission. The South Falls plant was purchased from the town of Gravenhurst and is also being enlarged. The other three plants were constructed by the Commission. In addition, power is purchased from the corporation of Orillia and from the Niagara system.

St. Lawrence System—This serves the district immediately to the north of the St. Lawrence river between Brockville and Cornwall. The supply of

power for the system is purchased under agreement from the Cedar Rapids Power Company, which generates its power at Cedar Rapids on the St. Lawrence river, delivery being made at a point near Cornwall.

Rideau System—This system serves the district in the vicinity of Smiths Falls, Perth, and Carleton Place. Power is available from two generating plants, one at Carleton Place and the other installed by the Commission at High Falls. Both plants are situated on the Mississippi river. The Commission also purchases power from the Rideau Power Company, of Merrickville.

Thunder Bay System—This system serves the district at the head of the Great Lakes, which includes the Twin Cities of Port Arthur and Fort William. Power is also supplied to the village of Nipigon and to pulp and paper companies. Power is obtained from developments on the Nipigon river. At present one site at Cameron Falls has been completely developed and a storage dam has been built at Virgin Falls below the outlet of lake Nipigon. Another development is being made at Alexander Landing and, as required, it is proposed to construct further developments on this river.

Ottawa System—This system serves the city of Ottawa and an extensive rural power district nearby. Power is purchased from the Ottawa and Hull Power and Manufacturing Company, which develops power at the Chaudière Falls on the Ottawa river adjacent to the city.

Central Ontario and Trent System—This system serves the district bordering the north shore of lake Ontario between the territory on the west served by the Niagara and Georgian Bay systems and that on the east served by the St. Lawrence and Rideau systems. The nucleus of the Central Ontario and Trent system was the group of properties formerly controlled by the Electric Power Company, Limited, and operated by it through the agency of twenty-two subsidiary companies. All these properties were purchased by the Province of Ontario on March 1, 1916. Since June 1, 1916, they have been operated by the Commission as trustee for the Province and the system has been greatly enlarged to meet the constantly growing needs of the district. In certain instances municipal corporations have entered into contracts with the Commission similar to those in force on the other systems. These municipalities are, for purposes of financial administration, grouped in what is termed the Trent system and receive power at cost. The power supply for the Central Ontario and Trent system is obtained from nine power developments situated on the Trent and Otonabee rivers, which have been made in conjunction with dams required for navigation purposes.

Nipissing System—This system comprises the town of North Bay and certain smaller municipalities adjacent to the southern end of lake Nipissing. It was purchased, together with the Central Ontario system, by the Province in 1916 and has since been operated by the Commission. It is supplied with power from two hydro-electric developments on the South river at Nipissing and at Bingham Chute.

Transmission Networks and Transformer Stations

In any comprehensive system for the supply of electrical energy to a large territory the ownership of the transmission lines and of the franchise rights for distribution, rather than the ownership of the power developments, is the dominating factor. At the outset of its operations the Hydro-Electric Power Commission proceeded to construct a network of transmission lines in order to link up with Niagara Falls the municipalities which first came into partnership. These transmission networks have extended rapidly and their growth has been accentuated at times by the inclusion and consolidation of existing smaller networks following the purchase of private companies formerly operating within these areas.

The main transmission lines of the Hydro-Electric Power Commission traverse routes aggregating about 3,800 miles in length and include more than 600 miles of steel-supported, 110,000-volt lines. The greatest length of continuous 110,000-volt line is that between Niagara and Windsor, a distance of approximately 250 miles. The new 220,000-volt line conveying power from the Gatineau river to Toronto has a length of 230 miles. In addition to the main transmission lines of the Commission itself, there are the distributing lines of the various municipal electric utilities totalling hundreds of miles in length. In connection with the rural power districts operated directly by the Commission, about 3,100 miles of primary distributing lines have been constructed, and many villages, hamlets and individual farmers are receiving the benefits of "Hydro" electrical service.

A fundamental part of the transmission systems are the transformer stations. In the Niagara system main transformer stations are strategically situated to receive current at 110,000 volts from the high-voltage transmission lines and transform it to a voltage suitable for distribution in the surrounding districts. The voltages employed on the main secondary lines are mostly 12,000, 13,200 or 26,400 volts. These secondary lines feed into municipal stations or distributing stations where further transformation takes place. The Niagara system operates at 25 cycles and all the other systems at 60 cycles.

Commission Assists the Municipalities

The Commission acts in an advisory capacity in connection with the operation of the "Hydro" utilities of the various municipalities with which it has contracts. In this connection the Commission arranges for the purchase or construction of distribution systems and assists the municipal officials in making their financial arrangements for the payment of the cost of these systems. The Commission also recommends all necessary rate adjustments, as provided under the Power Commission Act, and generally supervises the management and operation of all systems, more especially in the smaller municipalities, which, individually, are not of sufficient size to

TRANSMISSION LINE STRUCTURES—NIAGARA SYSTEM

QUEENSTON-CHIPPAWA POWER DEVELOPMENT

Control gate on power canal—48 feet clear span
Portion of completed canal in use, showing bridges
Forebay and rear of screen house

employ a manager with the technical knowledge necessary to administer properly all phases of the local system's operation.

As part of its service to the co-operating municipalities, the Commission has designed a uniform accounting system and the books of account of the local electrical utilities are kept in accordance with this system. Periodical inspections are made of the books of all "Hydro" electrical utilities and local officials are assisted in the improvement of their office routine with a view to standardizing as far as possible the methods employed. The standard accounting system ensures the employment of proper classifications of revenue and expenditures, saves time in the preparation of reports, and makes certain that the accounts represent as truly as possible the actual operating results for the year.

Electrical Inspection in Ontario

Certain functions of the Commission, including electrical inspection, are quite distinct from its activities as administrator of the hydro-electric undertaking. In connection with the generation and transmission of electrical energy, the Commission acts as agent and trustee of the co-operating municipalities. In so far as electrical inspection is concerned, however, the Commission is the servant of the Provincial Government, and its activities extend to all the municipalities of the Province, whether they are partners in the "Hydro" undertaking or not.

The object of electrical inspection is to eliminate, as far as possible, danger to person and to property through the misuse of electricity. The enforcement of the measures designed to protect the public from personal shock hazards and from the danger of fires is considered to be properly a function of public administration to be backed by legal authority. In matters of electrical inspection and approval of equipment, Ontario may be said to occupy a position of leadership.

In view of the fact that the Hydro-Electric Power Commission already had a highly-trained technical staff of electrical experts, the task of formulating a code of Rules and Regulations governing safety requirements for electrical installations was delegated to the Commission. The regulations were made part of the law of the Province and their enforcement through a system of inspection was also placed in the Commission's hands. The legislation providing for electrical inspection was enacted in 1912, and some years later the Provincial Government, through the Commission, provided facilities for testing electrical appliances and materials, and an Act was passed which provided that, unless approved by the Commission as safe for use, no such appliances and materials could be used or sold in the Province. The administration of these regulations is carried out by the Testing and Inspection department of the Commission.

ACHIEVEMENTS OF THE COMMISSION

Some idea of the various operations involved in the working out of the principles basic to this municipal undertaking may be obtained from the Annual Reports of the Commission. During recent years these Annual Reports have been volumes of several hundred pages. They give more information respecting the operation of the co-operative hydro-electrical enterprise of the municipalities of Ontario than is obtainable with respect to other districts from the published Reports of any other system of electric utilities, regardless of where operated or whether under public or private ownership.

The Annual Report contains a section describing the operation of the various systems of the Commission and sections dealing with new work under construction. It also records modifications in existing legislation; gives the text of any new statutory enactments relating to the Commission, and summarizes various other aspects of the Commission's work. Several of the sections are illustrated with interesting photographs and diagrams.

About two-thirds of the Report is devoted to statistical financial data which are presented in two sections known in recent Reports as Sections IX and X. Section IX presents in summary form the financial statements relating to the operations of the Commission in the generation, transformation and transmission of electrical energy *to the co-operating municipalities.* Section X presents in summary form financial statements relating to the operations of the local municipal electric utilities in the distribution of electrical energy *to consumers.* This section also contains details of the costs of electrical energy to consumers in the various municipalities and tabular statements of the rates in force. Explanations of the various Tables are given at the commencement of the respective sections.

Growth in Consumption of Electricity in Ontario Municipalities

The rapid growth in the demand for electrical energy by Ontario municipalities has already been referred to. The Annual Report contains a number of diagrams graphically illustrating the growths which have occurred in the loads on the various systems. The following tabulation shows the power taken by the various systems during the years 1926 and 1927:

DISTRIBUTION OF POWER TO SYSTEMS OF THE COMMISSION

20-Minute-Peak Horsepower

System Coincident Peaks

System	October 1926	December 1926	October 1927	December 1927
Niagara system	800,000	809,651	810,322	853,960
Georgian Bay system	17,109	18,191	19,247	21,791
St. Lawrence system	6,790	6,932	8,246	9,033
Rideau system	3,076	3,150	3,290	3,123
Thunder Bay system	40,977	45,640	43,603	42,332
Ottawa system	16,354	17,728	18,480	18,794
Central Ontario and Trent system	41,166	43,901	43,458	47,994
Nipissing system	2,560	2,697	3,054	3,225
Total	928,032	947,890	949,700	1,000,252

Financial Summaries*

The cumulative results to date of the operation of the several systems of the Commission as set forth in the Annual Reports demonstrate a remarkably healthy financial condition.

At the end of 1927 the total investment of the Hydro-Electric Power Commission of Ontario, in power undertakings and hydro-electric railways, was $204,372,066.84, and the investment of the municipalities in distributiing systems and other electrical assets was $81,792,678.34, making in power and hydro-electric railway undertakings a total investment of $286,164,745.18. The total revenue derived from this capital investment aggregated $34,056,707.88 in 1927.

For the purpose of financial statement, the various systems of the Commission are treated as separate units and for each of them similar statements and details are given in the Annual Report. Similarly, each municipal electric utility, or rural power district, is an independent financial unit within its respective system. In addition to the customary audits, the accounts of the Hydro-Electric Power Commission of Ontario are independently verified by auditors specially appointed by the Provincial Government. The accounts of the "Hydro" utility of each individual municipality are prepared according to approved and standard practice and are also duly audited.

The following statement shows the capital invested in the respective systems and in the local municipal undertakings:

CAPITAL INVESTED IN "HYDRO" UNDERTAKINGS

Niagara system	$157,273,132.98
Georgian Bay system	5,315,625.84
St. Lawrence system	1,328,384.25
Rideau system	1,173,928.46
Thunder Bay system	14,144,679.68
Ottawa system	143,441.05
Engineering—Power sites, Algoma District	7,288.23
Central Ontario and Trent system	14,260,456.10
Nipissing system	1,054,487.80
Hydro-electric railways	6,696,522.91
Office and service buildings, construction plant, inventories, etc. relating to all of the above properties	2,974,119.54
	$204,372,066.84
Municipalities' distributing systems and other assets (exclusive of $10,143,205.66 of municipal sinking fund equity in H-E.P.C. system)—all systems	$ 81,792,678.34
	$286,164,745.18

*It will be appreciated that the financial data which immediately follow are subject to change from year to year consequent upon the growth of the Commission's activities. The figures here given are for the year 1927. The compiled data for each year do not become available for publication until some months after the fiscal year has closed and are then published in the Commission's Annual Report for that year.

The following statement shows the combined revenue of the Hydro-Electric Power Commission and the municipal electric utilities:

COMBINED REVENUE OF COMMISSION AND ASSOCIATED MUNICIPAL ELECTRIC UTILITIES

Revenue of the Hydro-Electric Power Commission:		
From the municipal electric utilities, rural power districts, hydro-electric railways and other power customers	$19,024,604.32	
From rural consumers	978,923.64	
From the Central Ontario and Trent system, also Nipissing system and the pulp mill	2,328,173.17	
	$22,331,701.13	
From hydro-electric railways	1,205,406.00	
Total revenue of the Commission		$23,537,107.13
Revenue collected by the municipal electric utilities		24,583.022.13
Aggregate revenue of Commission and electric utilities		$48,120,129.26
Deduct:		
Revenue from power supplied to municipal electric utilities and hydro-electric railways		14,063,421.38
Combined revenue		$34,056,707.88

The following statement summarizes the Commission's collections from municipal hydro-electric utilities and other power customers for the year 1927 and shows how the collections were appropriated:

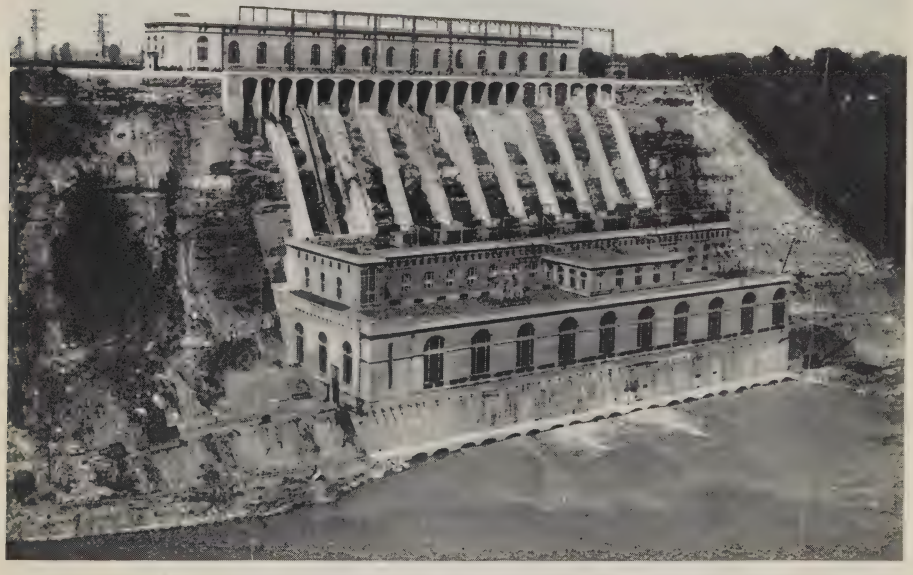
SUMMARY OF FINANCIAL OPERATIONS FOR THE YEAR 1927 OF THE HYDRO-ELECTRIC POWER COMMISSION

Revenue from municipal electric utilities and other power customers		$22,331,701.13
Appropriated as follows:		
Operation, maintenance, administration, interest and other current expenses	$16,404,769.61	
Reserves for sinking fund, renewal of plant and equipment and contingencies	5,392,734.59	
		21,797,504.20
Net surplus, after providing for all expenses and necessary fixed charges, credited to municipalities and shown in their accounts		$534,196.93

The following is a summary for the year 1927 of the financial operations of the hydro-electric utilities of the municipalities which operate under "at cost" contracts with the Commission:

QUEENSTON-CHIPPAWA POWER DEVELOPMENT

Screen house, Administration Building and Reception Hall. Forebay is to left and power house is at foot of cliff to right



QUEENSTON-CHIPPAWA POWER DEVELOPMENT

Queenston generating station as completed for nine units showing administration building and screen house above, with concrete covered penstocks descending the cliff. The Niagara gorge at this point is more than 300 feet deep from top of cliff to water level

QUEENSTON-CHIPPAWA POWER DEVELOPMENT

Interior of the great generating station at Queenston, constructed for the co-operating municipalities of Ontario by the Hydro-Electric Power Commission. View shows nine units—aggregating about 550,000 horsepower—installed, with two service units in foreground. Only the upper frame and exciter of each main unit are above floor level; the alternator proper and the turbine are encased in concrete

SUMMARY OF FINANCIAL OPERATIONS FOR THE YEAR 1927 OF LOCAL "HYDRO" ELECTRIC UTILITIES IN ONTARIO MUNICIPALITIES

Total revenue collected by the municipal electric utilities		$24,583,022.13
Cost of power, obtained from the Commission	$13,652,712.09	
Operation, maintenance and administration of local plants	4,681,466.93	
Debenture charges and interest in respect of local systems	3,694,855.76	
Depreciation on local plants	1,262,000.65	
Total		23,291,035.43
Surplus for the year, includes surplus from H-E.P.C		$ 1,291,986.70

The total reserves of the Hydro-Electric Power Commission and of the municipalities, in connection with their electrical utilities, for sinking fund, renewals, contingencies and insurance purposes, amounted at the end of the year 1927 to $65,434,540.24, made up as follows:

ACCUMULATED RESERVES OF THE HYDRO-ELECTRIC POWER COMMISSION AND OF THE LOCAL ELECTRIC UTILITIES OF THE CO-OPERATING MUNICIPALITIES

Niagara system	$23,673,222.79
Georgian Bay system	1,379,191.18
St. Lawrence system	333,995.98
Rideau system	212,547.72
Thunder Bay system	612,547.82
Ottawa system	12,555.63
Central Ontario and Trent system	2,105,281.05
Nipissing system	145,692.83
Bonnechère storage	11,201.61
Service buildings and equipment	465,903.62
Hydro-electric railways	156,332.18
Insurance—Workmen's compensation and staff pension insurance	1,820,545.72
Total reserves of Commission	$30,929,018.13
Total reserves of municipal electric utilities	34,505,522.11
Total Commission and municipal reserves	$65,434,540.24

Assets of Municipal Electric Utilities Increase More Rapidly than Liabilities

Notwithstanding the substantial reductions that have been made from time to time in the cost of electrical service to consumers, many of the municipalities in connection with their hydro-electric utilities have accumulated surpluses. It should specially be noted that, after providing for all its reserve funds, any net surplus that may accrue to the Commission in any year of its operations is not allowed to accumulate but is returned to the

municipalities. In the case of many of the local systems, however, the growth in consumption has been so rapid that, in spite of repeated reductions in rates, surpluses are accumulated each year. Obviously, it is not practicable to apportion and return surpluses to all the individual consumers and, moreover, it is necessary to work with a small margin of surplus over estimated costs. The annual surpluses thus created have for the most part been reinvested in extensions to the local systems and due to this practice the assets of the local systems have increased at a more rapid rate than their liabilities.

Low Rates for Electrical Service in Ontario Municipalities

The function of the Commission is not only to use its best endeavors to provide for the people of Ontario *at cost* an adequate and reliable supply of electrical energy, but also to ensure that the cost of that electrical energy to the consumers shall be a minimum. In this the Commission has achieved notable success.

The policy and practice of the Commission has been, and is, to make the widest possible distribution of electrical energy and to extend to every community that can economically be reached by transmission lines, the benefits of electrical service. One of the distinguishing features of the Commission's operations has been the widespread distribution of electrical energy to many consumers rather than a restriction of its efforts chiefly to the supply of very large blocks of power under long-term contracts to large industries.

The accompanying representative diagram—which is reproduced from the Twentieth Annual Report of the Commission—shows that the bulk of the electricity distributed by the co-operating municipalities is sold at strikingly low prices. It also shows that the total amount of the energy sold in the municipalities where, by reason of the distance from the source of supply or of the smallness of the quantity of power required, the cost per horsepower to the local utility—and consequently the cost per kilowatt-hour to consumers—must unavoidably be comparatively high, is relatively insignificant.

Throughout the municipalities of Ontario served by the Hydro-Electric Power Commission the use of electrical appliances is greatly promoted by the low cost of electricity. In most of these municipalities, the average family may take full advantage of the cleanliness, convenience and safety of electric lighting for less than $1.00 per month; while, for a small additional cost, irons, toasters, electric fans, washing machines, vacuum cleaners, and certain light cooking appliances may be utilized. Cooking by electricity is already popular and extensively employed in Ontario municipalities.

Scientific Rate Schedules

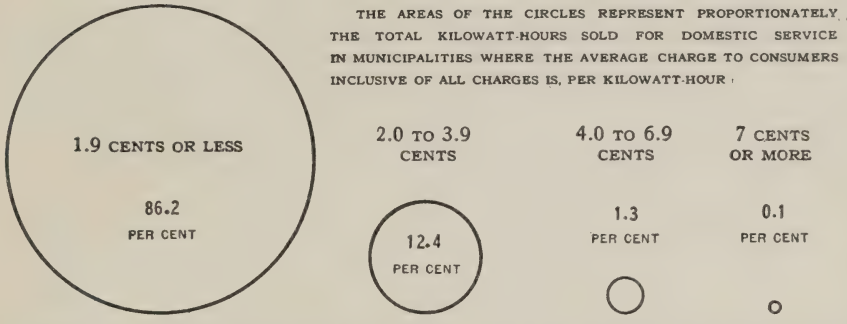
In pursuance of its fundamental principle of providing service "at cost", the Hydro-Electric Power Commission makes periodical analyses of the

COST OF ELECTRICAL SERVICE

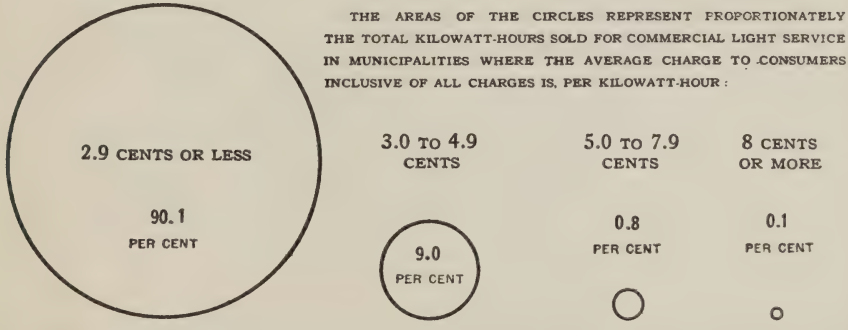
IN MUNICIPALITIES SERVED BY THE

HYDRO-ELECTRIC POWER COMMISSION OF ONTARIO

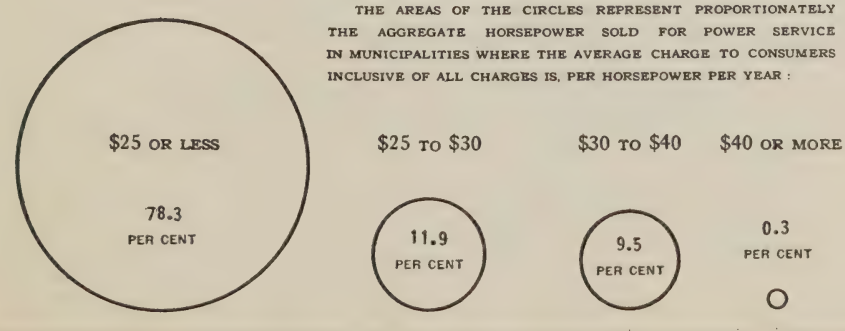
DOMESTIC SERVICE



COMMERCIAL LIGHT SERVICE



POWER SERVICE SUPPLIED BY MUNICIPALITIES



rates charged by the municipalities to consumers of all classes, in order to ensure that *each class* shall bear neither more nor less than its share of the expenses of the undertaking. The form of rate schedule for each class of service is designed to ensure, as far as is practicable, that each *consumer* is charged with the actual cost of the service he receives.

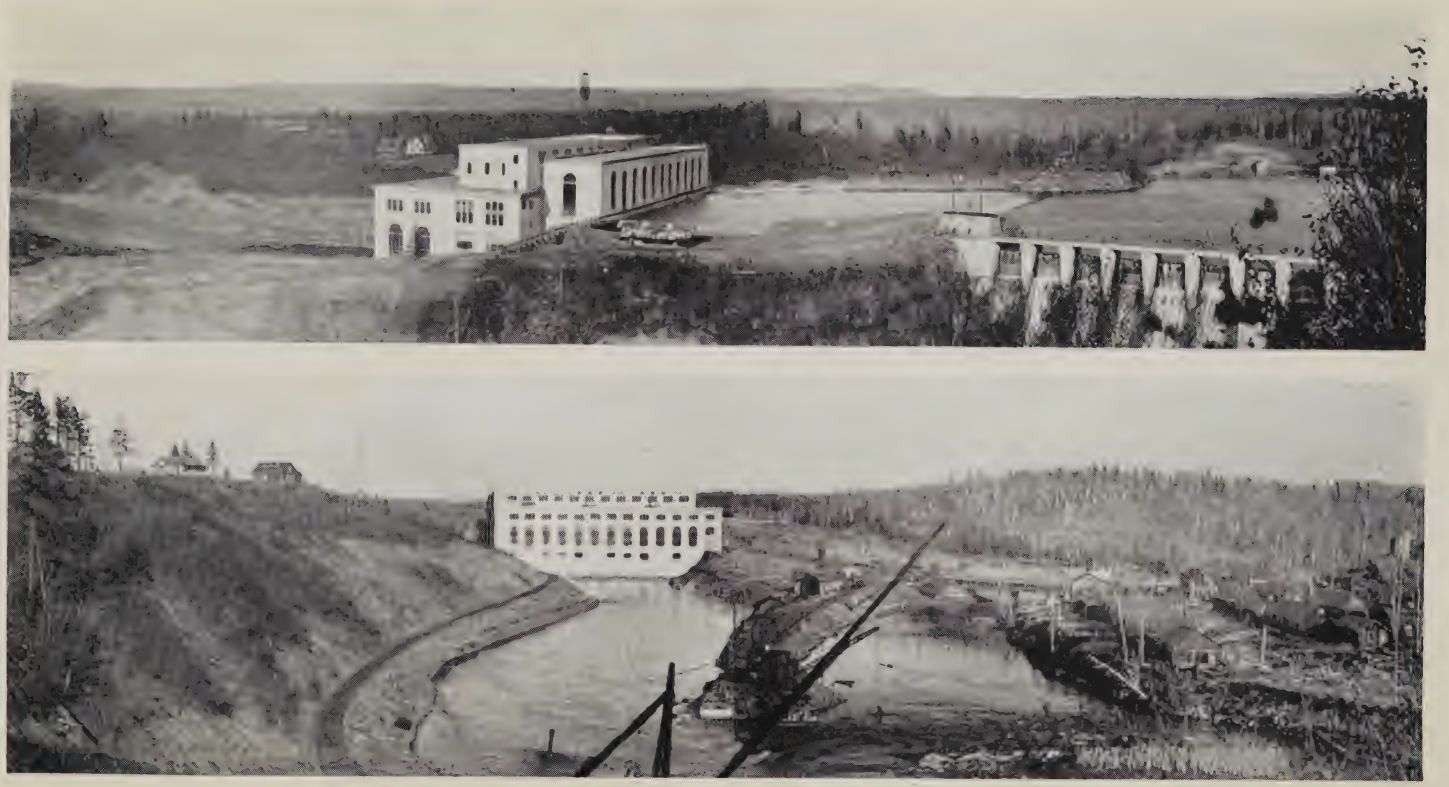
From the commencement of its operations, the Commission introduced in the municipalities which it serves, three-part rate schedules for each of the three main classes into which the electrical service is usually divided, namely: residential or domestic service, commercial light service, and power service. In the sphere of domestic service, the adoption of this scientifically designed schedule of rates, together with the low rates resulting from the policy of distributing "at cost", resulted in a remarkable increase in the consumption of electricity; this, in turn, automatically caused further reductions in the rates charged, and this again, increased consumption. In many municipalities the secondary or follow-up rate, that is, the rate applicable for all energy used over a certain consumption per month, is as low as 0.9 cents net per kilowatt-hour, and, several years ago, the Commission inaugurated a scheme whereby the "follow-up" rate in nearly all "Hydro" municipalities is, for domestic service, 1.8 cents net or less per kilowatt-hour. Moreover, the "follow-up" rate, which varies in different municipalities from 0.9 to 1.8 cents per kilowatt-hour, applies after a relatively small consumption of energy at the primary rate; and furthermore, where the higher rates prevail the number of kilowatt-hours paid for at the primary rate is smaller. Except in a few quite small municipalities where exceptional circumstances exist, domestic consumers in Ontario cities, towns and villages, before their net monthly bill has reached the sum of $2.50, obtain "all additional" electrical energy at a rate of 1.8 cents per kilowatt-hour or less.

Under the guidance of the Commission many of the municipal electric utilities of Ontario have been able to reduce the cost of *distribution* for domestic service until it is substantially less than one cent per kilowatt-hour. Since power is provided *at cost* and distribution is *at cost* this has resulted in low cost to the consumer. Under the stimulus of lower cost, average consumption has substantially increased. The average annual consumption per consumer for domestic service in 120 municipalities of Ontario exceeds 600 kilowatt-hours per annum. In more than 50 of these municipalities there is an average consumption per consumer in excess of 1,000 kilowatt-hours per annum; in 23 there is an average consumption of 1,500 kilowatt-hours or more, and in 9 an average consumption of 2,000 kilowatt-hours or more.

One of the tables of the Annual Report—Statement "D"—presents some interesting data regarding the average charges for electric light and power service in each municipality. The following table summarizes for a few representative communities—note the populations—the average charges for electrical service.

NIPIGON RIVER POWER DEVELOPMENTS—THUNDER BAY SYSTEM

Virgin Falls dam at outlet of Lake Nipigon
Cameron Falls generating station—Interior view showing six units installed
Alexander power development—Main dam under construction



NIPIGON RIVER POWER DEVELOPMENTS—THUNDER BAY SYSTEM

Cameron Falls generating station. General views showing forebay and main dam at right in upper view, and tailrace in lower view

CHARGES FOR ELECTRICAL SERVICE IN REPRESENTATIVE ONTARIO MUNICIPALITIES

Municipality	Population 1927	Approximate transmission distance in miles	Average net charge to consumers inclusive of all charges*		
			Residence service cents per kilowatt-hour	Commercial light service cents per kilowatt-hour	Power service dollars per horsepower per year
			cents	cents	$ c.
Toronto	549,429	78	1.6	2.4	24.81
Hamilton	122,459	53	1.6	1.2	16.75
Ottawa	118,697	1†	0.9	1.6	14.63
London	64,274	123	1.5	1.8	20.87
Windsor	56,433	238	1.6	1.9	25.49
Brantford	27,410	79	1.5	1.1	20.17
Kitchener	25,592	95	1.6	1.9	21.74
St. Catharines	22,043	18	1.2	1.5	15.88
Peterborough	21,495	2†	2.1	2.4	18.97
Guelph	19,230	75	1.7	2.2	18.47
Port Arthur	17,388	73†	1.4	1.8	20.52
Niagara Falls	17,380	1	1.2	1.4	21.96
Sarnia	16,058	205	2.0	2.3	34.85
Chatham	14,142	193	1.8	2.4	24.98
Ford City	12,689	239	1.7	2.4	27.31
Owen Sound	12,339	32†	1.8	1.7	16.82
Woodstock	10,140	94	1.5	1.9	17.11
Walkerville	9.071	239	1.4	2.1	26.79
Midland	8,085	25†	1.6	1.9	19.38
Barrie	7,339	48†	1.6	1.9	20.94
Collingwood	6,002	24†	2.4	2.9	20.67
Dundas	5,005	52	1.8	2.0	17.27
Paris	4,234	76	1.6	2.2	18.94
Picton	3,206	33†	2.2	2.2	21.71
Aylmer	2,158	145	2.3	2.3	25.09
Waterford	1,061	94	1.8	2.3	43.06

Rural Electrification

In many parts of the world, much attention is now being paid to rural electrification. In Ontario, there is a general recognition on the part of the Government, and of the citizens at large, that for a well-balanced development of the provincial resources, not only manufacturing industry, but also agriculture should profit by the extension of electrical facilities. Brief reference may, therefore, here be made to some of the results achieved by the Hydro-Electric Power Commission of Ontario in bringing to small rural

*It should specially be noted that the cost *per kilowatt-hour* or *per horsepower* as a criterion by means of which to compare the relative economies of electrical service in various municipalities, should only be applied when full account is taken, respectively, of the influence upon costs of such factors as the distance from source of power, the features of the power development from which service is received, the sizes and concentrations of adjacent markets for electricity, and the sizes and character of the loads supplied by the local electrical utility to the ultimate consumers. Actual bills rendered for similar service under strictly comparable circumstances constitute the best basis for effecting comparisons.

†Power supply from smaller generating stations not on the Niagara river.

communities and to individual farmers the inestimable advantages of electrical service.

At the outset, however, it should be appreciated that the amount of electricity distributed to the rural districts of Ontario is, and possibly must always be, but a relatively small proportion of the total energy distributed by the Commission. From the standpoint both of total energy distributed and of financial operations involved, the rural work of the Commission, important though it is, represents at present less than three per cent of the Commission's activities. It should, moreover, be noted that it is the widespread distribution of energy to the co-operating municipalities of the Province which has made possible the electrical service supplied to the rural dwellers. Without the transmission networks that have been constructed to serve the cities and towns of the Province any extensive rural electrification would be economically impossible.

The difficulties of electrification of country districts, although well understood by those engaged in the business of electrical supply, are not always fully appreciated by others. Primarily, the difficulty is one of scattered population resulting in relatively high annual charges per consumer for the capital investment in the necessary transmission and distribution lines. The operating costs, due to the distances to be covered, are comparatively high and the load per mile of distribution line is small—compare, for example, the number of services connected in a mile of city streets and along a mile of rural line. Moreover, in rural areas weather conditions largely determine the day-by-day demand for power and, since they affect most farmers in a given locality in a similar manner at the same times, the demand for electrical energy is irregular and consequently the load factor is low.

In Ontario the average farm is one of from 100 to 200 acres, and only in certain districts can more than five or six farms be served per mile of distribution line. The minimum requirement of the Commission in this respect is three farm contracts per mile of distribution line. The rural power districts also include hamlets and in these, of course, more customers are secured per mile of line. The results secured in Ontario are not on a comparable basis, and therefore should not be compared, with those secured in irrigation districts where the power used for pumping carries most of the capital charges and where, as a rule, the population per square mile is higher.

In spite of the handicaps inherent in rural distribution of electrical energy, the Hydro-Electric Power Commission has made substantial progress in this department of its activities. While the Commission has been studying the problem of rural power supply for many years, and its first rural lines were built in 1912, it was not until the introduction of amended legislation in 1920 that the present era of expansion in rural electrification received its real impetus. Under this amended legislation, zones or districts are determined in which electrical service is given to each of certain specified

classes, and throughout the whole district, at the same rates, based on average conditions in the district. These districts are known as "rural power districts" and are operated directly by the Commission. Their boundaries are not arbitrary geographical limits, but depend rather upon the economical distances which may be served from a distribution centre of city, town or village.

The supplying of rural electrical service in Ontario has not been simply a casual and spasmodic extension of transmission lines to a few specially favored and closely-settled districts along main highways adjacent to large cities. It has been the result of a real endeavor to give rural electrical service according to a comprehensive and carefully thought-out program. The total length of rural lines at present operated by the Commission is more than 3,150 miles, giving electrical service to about 25,000 customers in 122 rural power districts.

Provincial Government Encourages Rural Electrification by "Grants-in-aid"

The Ontario Government, having long recognized the benefits of hydro-electrical service to the agricultural industry of the Province, passed, in 1921, legislation authorizing the payment of a *grant-in-aid,* up to 50 per cent of their cost, in respect of rural primary lines on highways throughout the Province; in 1924, the grants were further extended, so that, under existing legislation, the Government of the Province of Ontario now pays 50 per cent of the *capital cost* of the installation of rural transmission lines and equipment necessary to deliver power from the distribution centre of city, town or village to the boundary of the rural consumers' property.

Concurrently, the Commission has developed and standardized highly economical methods of rural line construction and operation which have substantially reduced the cost of supplying rural service.

The assistance given by the Province to farmers and rural residents in the form of a grant towards the capital cost of supplying electrical service is in pursuance of a long-established governmental policy of promoting in various ways the basic industry of agriculture. This policy had previously found expression in the establishment of agricultural schools, colleges and experimental farms, in assistance for road building and in other ways.

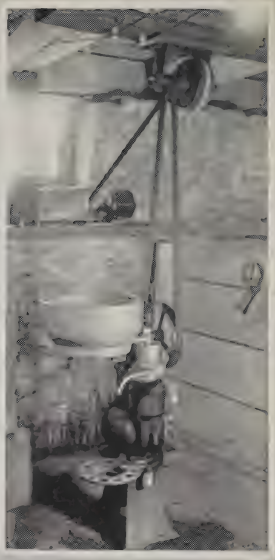
A misconception has existed in certain quarters respecting the extent and effect of the Ontario Government's financial assistance with respect to the distribution of power in rural districts. It has sometimes been stated that the provincial Government pays half the cost of rural electrical service. This is by no means the case, and the grant-in-aid towards the capital cost should not be confused with the rates for service. Having made its grant-in-aid, the Government's participation in operations respecting the property to which the grant applies ceases. Each rural power district administered by the Commission not only pays its cost of operation, maintenance and administration of these lines, but also sets up reserves for renewals and con-

tingencies *on the whole* of the equipment and lines, as well as providing interest and sinking fund on the investment made by the local authorities.

Rural Uses for Electricity

The widespread use of certain modern conveniences such as the radio, the telephone and particularly the automobile, has brought the rural dweller into very close touch with the life of the cities, while the annual fairs and exhibitions have made him familiar with the application of electrical appliances and machinery as used in other spheres of activity. Notwithstanding this, the conception which many rural residents at first have of their needs in the way of electrical service is frequently confined to lighting requirements. It is, however, becoming more and more realized that the greater service which electricity can render is in the form of convenient power, because it is in connection with power service that the farmer effects his chief saving in labor. The appliances that are so helpful to the city dweller, such as washing-machines, irons, fans, etc., are of even greater help to the farmer's wife; but, in addition, the farmer can make use of a large number of devices which are still more effective in labor saving than those used in the city, such, for example, as water pumps, cream separators, churns and milking machines, which can all be operated by quite small motors. Where electrical service of larger capacity can economically be installed, additional machinery, such as buzz- and drag-saws, choppers, root-pulpers, ensilage cutting-boxes and threshers, for which the farmer usually employs auxiliary power, can also be operated electrically. In this connection, it should be noted that farmers frequently instal machinery larger than is really necessary for the work that has to be done, but when the work is performed electrically it may often be accomplished more profitably by smaller machines requiring less power. As rural distribution of power extends, power-driven machinery will be employed with increasing regularity, and manufacturers will co-operate with power distributors and with the farmers themselves to secure the development of a better type of farm power-using machinery, specially designed for operation by electric drive.

There is another sphere in which electrical service has been of benefit to the rural dweller, namely, in the supplying of convenient power to local industries. It is very interesting to observe the rapidity with which industrial uses for electrical energy multiply once an electrical supply is available. In almost every rural power district there are some industries using power, such as brickyards, tile yards, cheese and butter factories, gravel plants, stone plants, quarries, chopping mills and flour mills. Such long-established industries develop and expand under electrical service, while the service also attracts new industries. There have been several old-fashioned, portable saw-mills supplied with electricity, the slabs of wood and sawdust being now sold for other purposes instead of being used, as formerly, for fuel for a steam plant employed to supply the power.



RURAL ELECTRIC SERVICE IN ONTARIO

Electrical milking
Rural scene
Motor driving pump
Motor driving cream separator
Electrical service to a farm
Motor driving feed chopper

RURAL ELECTRICAL SERVICE IN ONTARIO

Ontario farm home
Electric lighting and cooking
Washing machine and appliances
Electric power in cheese factory
Electric service to barn
Electric service to cheese factory
Laying underground cables
Overhead rural transmission

Rural Rates are Favorable

Respecting the cost of electric service to rural customers, the rates are based upon service "at cost" and, as in urban centres, are made up of two parts, a service charge and a consumption charge. The service charge depends primarily upon the individual connected load or demand, which feature determines in which of the several classes of service the farmer's contract will be placed. The consumption charge is in the form of a first and second kilowatt-hour charge based upon the cost of power at the point of delivery.

Although the rates for rural electrical service—due to the service charges necessary to cover annual costs appertaining to the capital invested in lines, etc.—are necessarily higher than in the cities, nevertheless the actual charges for the energy used are very favorable. To the farmer, therefore, who takes full advantage of the possibilities of labor-saving devices and makes a generous use of appliances, both on the farm and in the home, the average cost of service, even on the basis of cost per kilowatt-hour, is by no means excessive.

As typical of the charges that obtain in rural power districts, it may be stated that for the class known as "light farm service" (Class III), which includes the lighting of farm buildings, power for miscellaneous small equipment, power for single-phase motors not to exceed 3-horsepower demand or for an electric range—the range and motors not being used simultaneously—the gross monthly service charge varies from $4.55 to $2.50. For "heavy farm service" (Class VI), which includes, in addition to the above, power for motors up to 5-horsepower demand and electric range, or 10-horsepower demand without electric range, the gross monthly service charge varies from $7.35 to $4.05, according to the circumstances governing in the respective rural power districts. It should be recognized that farm electrical service as given by the Commission is essentially power service, and that in the cities and towns a service charge of $1.00 per month per horsepower of connected load or demand is charged for power service. In addition to the service charge a consumption charge at two rates is made. The first rate ranges from 3 to 8 cents per kilowatt-hour, depending in part upon the wholesale cost of power at the receiving station, and in part upon the length of time the rural power district has been in operation and the average use made of the service. Other things being equal, the greater the average consumption, the lower the first rate. This first rate is charged for the first 14 hours' use of the class-demand rating, which varies with the class demand. For Class III it is 3 kilowatts, and the first rate applies to the first 14 x 3 kw. = 42 kw-hrs, and for Class VI it is 9 kilowatts and the first rate applies to the first 14 x 9 kw. = 126 kw-hrs. The second rate, which applies to all additional consumption, is, in nearly all cases, two cents per kilowatt-hour; in a few districts, it is 1.5 cents per kilowatt-hour. There is a prompt payment discount of 10 per cent which applies to the whole bill if paid within ten days.

The following table gives representative examples of the cost of electrical service as supplied to farmers in rural power districts.

TYPICAL COSTS OF ELECTRICAL SERVICE TO FARMERS IN RURAL POWER DISTRICTS

Class	Annual consumption	Annual net cost to consumers inclusive of all charges					
		At standard initial rate (a)	Cost per kw-hr.	At 10 per cent less than standard rate (b)	Cost per kw-hr.	At 20 per cent less than standard rate (c)	Cost per kw-hr.
	kw-hrs.	$ c.	cents	$ c.	cents	$ c.	cents
III	500	71.64	14.3	62.28	12.5	52.92	10.6
light	1,000	80.75	8.1	71.35	7.1	61.96	6.2
farm	1,500	89.75	6.0	80.35	5.4	70.96	4.7
service	2,000	98.75	4.9	89.35	4.5	79.96	4.0
	4,000	134.75	3.4	125.35	3.1	115.96	2.9
IV	1,000	91.98	9.2	79.56	8.0	66.60	6.7
medium	2,000	109.98	5.5	97.56	4.9	84.60	4.2
farm	3,000	127.98	4.3	115.56	3.9	102.60	3.4
service	5,000	163.98	3.3	151.56	3.0	138.60	2.8
	10,000	253.98	2.5	241.56	2.4	228.60	2.3
VIa	5,000	210.20	4.2	188.49	3.8	167.32	3.3
heavy	7,000	246.20	3.5	224.49	3.2	203.32	2.9
farm	10,000	300.20	3.0	278.49	2.8	257.32	2.6
service	15,000	390.20	2.6	368.49	2.5	347.32	2.3
	20,000	480.20	2.4	458.49	2.3	437.32	2.2

(a) Service charges: Class III, $4.55; Class IV, $4.75; Class VIa, $7.35 per month.
Consumption charges: First rate, 5 cents per kw-hr., Second rate, 2 cents per kw-hr.
NOTE: In districts well established the service charge, as more consumers take service is reduced to 10, 15, 20, or more per cent below standard. At the same time the first kw-hr rate goes down by reason of increased use.
(b) Service charges: Class III, $4.10, Class IV, $4.30, Class VIa, $6.60 per month.
Consumption charges: First rate, 4 cents per kw-hr.; second rate, 2 cents per kw-hr.
(c) Service charge: Class III, $3.65; Class IV, $3.80; Class VIa, $5.90 per month.
Consumption charges: First rate, 3 cents per kw-hr.; second rate, 2 cents per kw-hr.

The energies of the Commission's engineers have been directed to ascertaining the most economical methods of rural distribution. Much pioneer work has already been undertaken and the results achieved have more than justified the efforts. Agriculture still ranks as the most important of our industries for, as is universally acknowledged, upon the farmer, in the last analysis, rest the prosperity and welfare of the community. The influence upon the economic life of the Province of Ontario of the rural electrical service supplied through the Commission is already a factor of great social importance.

Power Supply for the Commission's Systems

It has been explained that the supply of power for distribution by the Commission was first secured from private companies having extensive developments already made at Niagara Falls. From time to time municipalities in districts adjacent to other sources of hydro-electrical energy requested the Commission to take action with a view to supplying their power needs. In some cases, the power supply for these other systems was obtained, as in the case of the Niagara system, from existing developments. In other cases the Commission found it necessary to construct power developments. The developments constructed by the Commission differ from each other not only in physical characteristics, but also in their economic relationships to the various systems which they supply, as well as to the Commission's undertaking viewed in the large. It is not profitable to present in this pamphlet a detailed description of all the power developments operated by the Commission. Many persons, however, will be interested in brief descriptions of the larger power developments supplying the Niagara system, and also in a few facts relating to some of the more interesting of the power developments constructed by the Commission to supply other systems. For convenience these descriptions have been grouped together and will be found on pages 33 *et seq.*

Sources of Future Electrical Energy

Although the "Hydro" undertaking was initiated with the use of purchased power—and the Commission has not hesitated to make use of purchased power as and when found desirable in the best interests of municipalities—nevertheless the bulk of the electrical energy supplied by the Commission comes from the twenty-two publicly-owned hydro-electric developments operated by the Commission.

There are three main sources for additional supplies of hydro-electrical energy to serve the existing systems in southern Ontario. On the international portion of the St. Lawrence river, it is possible to make developments, either at one or at two sites, with an aggregate installed capacity of about 2,000,000 horsepower, half of which belongs to Canada in the right of the Province of Ontario. On the Ottawa river, which is an inter-provincial stream, the power is distributed along the river at a number of sites. In the aggregate, with regulated stream flow, the river may be made to yield about 1,000,000 horsepower, half of which belongs to Ontario. On the Niagara river, the amount of power that can be developed at present is limited by the amount of water that can be diverted under the terms of the Boundary Waters Treaty of 1909-10. Substantial increase in power may be obtained from further allotment of water.

On the international portion of the St. Lawrence river, stretching from lake Ontario to St. Regis below Cornwall, there is a fall of a little more than ninety feet, and between eighty and eighty-five feet of this fall can be

developed for power by building a series of dams and dykes, either concentrating the total fall near Cornwall at the foot of the Long Sault or making a two-stage development concentrating a portion of the head at a point near Chrysler island or Morrisburg and the remainder at the foot of the Long Sault. The two-stage scheme would cause much less loss through flooding, and power would be available earlier and under desirable circumstances. In either scheme, the requirements of improved navigation would be provided for and fully safeguarded.

The question of the development of the St. Lawrence river as a whole in the interests of power and navigation is a complex one, owing to the varied governmental and other interests involved both in Canada and the United States. The development of the international portion of the river for power, however, although in itself a large undertaking, and one which cannot satisfactorily be solved without a broad consideration of its relationship to the larger issues involved, does not present some of the international and economic problems which have to be considered in a project for the complete development of the river for navigation and power from the Great Lakes to the Sea. In the international reach of the river the problem may be said to be rather an engineering or physical one, because from the economic standpoint of power there is—or will be as development is completed—a market awaiting all the power that can be developed, not only in the United States for its share, but in Canada also. And it is a relatively simple matter to make provision in the power dams for such locks and other structures as are required for improved navigation. Respecting the physical aspects of the improvement, the Hydro-Electric Power Commission has made important contribution to the investigations that have been made. In 1921 the Commission submitted to the International Joint Commission the results of its special surveys and research, together with complete plans and estimates for alternative schemes of development. In 1925, in order to be available for official reference, this Report was printed with the original plans and brought up to date.* Since this time the problem has been under consideration by other investigating bodies appointed by the United States and by the Dominion of Canada.

On the Ottawa river there are several large power sites. The total power available depends in large measure upon the storage provided and the degree of regulation of the flow effected. Power development upon this river has been held back awaiting the co-ordination of the various interests and existing rights involved. During recent years, however, substantial progress has been made. Supplementing the surveys made by the Georgian Bay Canal Commission, which were made largely from the standpoint of

*Consult: *Statement and Engineering Report by the Hydro-Electric Power Commission of Ontario Submitted to the International Joint Commission Respecting the Proposal to Develop the St. Lawrence River, 1921.* 8vo, 119 pp., with 13 coloured plates. Toronto, 1925. Issued for reference purposes only at a nominal price of $7.50; not available for free distribution.

POWER DEVELOPMENTS SERVING THE GEORGIAN BAY SYSTEM

Hanna Chute development—South Muskoka river
Eugenia Falls development—General view
Eugenia Falls development—Interior view
Big Chute development—Severn river
Eugenia Falls development—Surge tanks
South Falls development—General view
Wasdells Falls development—General view
Wasdells Falls development—Interior view

POWER DEVELOPMENTS SERVING THE CENTRAL ONTARIO AND TRENT SYSTEM

Panoramic view of development at Dam No. 9
Dam No. 8 power development—exterior and interior views
Panoramic view of development at Heeley Falls
Ranney Falls power development, looking into tailrace. Heeley Falls power development, interior

navigation, the Hydro-Electric Power Commission has made extensive surveys of the Ottawa river from the standpoint of power development.

On the Niagara river, the water available under Treaty terms is practically all in use on both sides of the boundary. No further power development can be made until there has been an enlargement of present Treaty allotments. Here every cubic foot of water under the full head can produce thirty horsepower. Thus, say, 10,000 cubic feet of water would produce 300,000 horsepower.

Notwithstanding the rather slow progress that has been made respecting the development of these international and inter-provincial water powers, the Commission looks forward to the time when it will be able to construct, on behalf of the co-operating municipalities of Ontario, further large power developments, each contributing its quota of power for the growing industrial, municipal and domestic needs of the citizens of this Province.

Much Unjust Opposition

Since the year 1910, the Hydro-Electric Power Commission has been successfully distributing electrical energy to the co-operating municipalities of the Province in ever-increasing quantities until to-day it ranks with the first four or five largest distributors of electrical energy in the world and in certain phases of its operations stands first. Being a public ownership undertaking, this prominent position, naturally, has not been attained without opposition. To well-intentioned and constructive criticism the Commission does not object, but much of the criticism that has been directed against it has been of a character distinctly unjust. Probably no public undertaking has experienced more unfair misrepresentation than has the work of the Hydro-Electric Power Commission of Ontario, but for the most part the Commission has been content to ignore these attacks and concentrate upon the work in hand. There were, however, certain outstanding attempts to discredit the work of the Commission which, although published with the earmarks of authority, were so unprincipled in their misrepresentation that the Commission, in the interests of the municipalities, deemed it wise to refute them by formal statements. Certainly, the opposition experienced would not have been so long continued against an unsuccessful venture, and it is significant that the attacks have come, not from the benefitting municipalities, but from outside sources. The citizens of Ontario know that their enterprise is a great success and of this they are reminded every time they receive their relatively small bills for electric power and light at cost.

Pioneer Work by the Commission

No recital of the achievements of the Hydro-Electric Power Commission of Ontario would be complete without brief reference being made to a few representative instances in which the Commission has pointed the way to advances in the art of public utility engineering. The ideas thus pioneered

by the largest publicly-owned electrical utility in the world were in many cases put into practice by the Commission years in advance of their general adoption.

Co-ordinated Supply and Interconnection: Within the last few years there has been a great deal of discussion on the subject of "superpower", by which is meant the system of generation and supply whereby the many important benefits accruing from the co-ordination of the requirements of many communities by means of interconnection are secured. The advantages of the "superpower" idea have, however, been recognized in Ontario ever since 1902, and co-ordinated supply to many municipalities is, and has always been, one of the fundamentals of the enterprise of the Hydro-Electric Power Commission of Ontario, with the result that, at the present time, the Commission furnishes electrical service to more than 200 of the cities, towns and villages of the Province. It also supplies many townships, police villages, and rural districts. In all, more than 500 organized municipalities receive power through one Commission. The Commission operates twenty-two hydro-electric generating plants, and interconnection has been employed for many years to yield the maximum benefit possible under geographic and economic limitations.

Centralized Technical Supervision: The recent and current extensions of holding company operations is evidence that the benefits of centralization of technical supervison—another of the Commission's fundamental principles since its initiation—are only now being put into practical application on an extensive scale by privately-owned utilities.

Scientific Rate Schedules: A leading technical journal warmly commended the enterprise of a New England privately-owned electrical utility for having in comparatively recent years had the courage to put into effect a three-part rate for electrical service, and the same editorial deplores the continued use of unscientific rate schedules by the industry in general. The municipalities served by the Hydro-Electric Power Commission of Ontario have for the last seventeen years employed standard three-part rate schedules constructed according to principles only now beginning to be adopted by many privately-owned utilities.

The World's Largest Single Hydro-Electric Power Development: The Commission's Queenston-Chippawa development has been universally recognized as an engineering achievement of the first rank. It is the only plant to utilize the full economic head between lakes Erie and Ontario, and develops approximately double the amount of power from the same flow of water, as compared to the average of the earlier plants at Niagara Falls, all of which were constructed under private enterprise. The new turbines and generators were, at the time of their installation, not only the largest but the most efficient of their kind in existence.

Rural Electrical Service: Notwithstanding the absence of power loads, such as are produced by the requirements of irrigation, to bear the bulk of

the fixed charges, and in spite of the sparsity of population in rural Ontario due to the practice of including large acreage in each farm, more than 3,000 miles of rural distribution lines have been constructed in the last twelve years. Furthermore, a special system of underground cable distribution for rural work has been developed which has been found advantageous for certain special conditions. In the matter of rural work, the Hydro-Electric Commission of Ontario has indeed been a pioneer.

Pioneer in High-Voltage Transmission Standards: In the field of high-voltage transmission, the Commission has operated 110,000-volt lines since 1910, the greatest continuous distance of transmission being about 250 miles. The Commission has contributed substantially to the design of suspension-type insulators—for instance, the ball-and-socket joint now in almost universal use was originated by the Commission. In many other ways the Commission has pioneered in high-voltage transmission practice.

Extensive Special Laboratories Established: The Commission maintains well-equipped laboratories staffed by engineers and scientists of world-wide reputation, the primary object of which is to advance the electrical art. The fullest co-operation is afforded to other research bodies in the effort to extend the sum of knowledge both in the field of engineering and of pure science. To gain an appreciation of the achievements of the Commission's laboratory engineers, it is only necessary to consult the publications of the prominent engineering and scientific societies. In 1923, for instance, the "First Prize" for papers presented before the American Institute of Electrical Engineers was awarded to one of the Commission's engineers.

Improvement in Concrete: An outstanding achievement of the Materials Testing Division of the Commission's laboratories is in the development and perfecting of a practical system of scientific field control of concreting operations, covering all steps in the making of concrete, from the inspection of the raw material to the curing of the finished product. This has been the means of effecting important economies in construction work.

Methods of Electrical Measurement Advanced: Studies of operation requirements have resulted in the development of a new type of demand meter, a new and improved method of totalizing distant loads at a central point, simplified methods of testing instruments and of making alternating-current measurements, new instruments for measuring the efficiency of electrical apparatus and the speed of rotation of power units, improved methods of detecting defective insulators and of locating faults in buried cable, and development of guided-wave methods of radio communication for use under adverse weather conditions.

On more than one occasion it has been stated that public ownership has never developed any useful device or method, and that it lacks initiative. The foregoing instances are representative of the many features of original

engineering and scientific research contributed by the Hydro-Electric Power Commission of Ontario in its constant efforts to advance the electrical and mechanical arts, and given to the world through technical publications. They are amply sufficient to demonstrate that lack of initiative, either in scientific achievement or in the application of business methods, has in no sense characterized the publicly-owned electrical utilities of Ontario.

Success the Result of Many Factors
Co-operation and Confidence Essential

In this publication there is presented in broad outline what has been accomplished by co-operating municipalities in the Province of Ontario in the matter of supplying electrical energy to their citizens. The whole program has been carried out with special regard to the circumstances which characterize Ontario conditions, and special research was first conducted for the purpose of ascertaining just what were the underlying essential circumstances. It should be appreciated that several prominent factors relating to electrical service in the Province of Ontario, may, and do, differ markedly from those prevailing in other territories. Sometimes an injustice has been done to the work of the Commission, as well as to others, through comparisons being made between its work and what it has been *assumed* might be accomplished in other territories, when no real basis for comparison has been established. Each set of conditions should be independently appraised upon its own merits. Recognizing this important fact, the Commission has refrained from any effort to urge its municipally-owned program as being suitable for wholesale adoption elsewhere.

Where any may desire to compare the results achieved by the Hydro-Electric Power Commission of Ontario with those secured elsewhere, a simple and direct method is to compare the amounts of the monthly bills rendered to consumers under corresponding circumstances of service and for comparable quantities of electrical energy.

For the success of such an enterprise as the electrical undertaking of Ontario municipalities many factors must combine. One of the most important is the establishment and maintenance of the most complete confidence between the central organization and the co-operating municipalities. This confidence has characterized the whole life of the Ontario undertaking. In a work of such magnitude, issues—perhaps sometimes of a controversial nature—must inevitably arise in one community or another. It is remarkable, however, how seldom such issues do arise and from actual experience the Commission is able to state that these local differences can always be adjusted. Satisfactory adjustment is largely a question of sincere co-operation.

The Hydro-Electric Power Commission has had thousands of requests for information respecting its operations and it is hoped that this pamphlet dealing with its origin, administration and achievements will place those interested in possession of the essential facts.

POWER DEVELOPMENTS

In the foregoing pages there have been considered general features relating to the origin, administration and achievements of the "Hydro" undertaking. Many readers will be interested in brief descriptions of some of the hydro-electric developments which supply power to the systems of the Commission. In this connection, there will first be given descriptions of the power developments of the Niagara system, and these will be followed by brief accounts of some of the smaller developments possessing features of special interest.

Power is supplied to the Niagara system from three generating plants known respectively as the Ontario Power generating station, the Toronto Power generating station and the Queenston generating station. The last-named is the largest single hydro-electric power development in the world and attention is first directed to some of its more important features.

Queenston-Chippawa Power Development

The general scheme of development comprises an intake structure in the Niagara river at Chippawa; the deepening and enlarging of the Welland river, with a reversal of its flow for 4 miles; the construction of a canal 8¾ miles long from Montrose on the Welland river to the forebay and screen house, which are situated on the cliff above the power house on the lower Niagara river where the banks rise more than 300 feet above the water level, about one mile south of the village of Queenston.

Previous power developments on the Niagara river utilized only that portion of the total fall of the river which occurs in the vicinity of the falls, and, for the most part, even this amount of head had been inefficiently utilized; but the basic conception of the Queenston-Chippawa development is the utilization of the greatest possible amount of the total fall of the Niagara river between lake Erie and lake Ontario at the highest possible efficiency. Of this total fall of 326 feet, about 12 feet occurs in the upper Niagara river from lake Erie to Chippawa and in the lower river from Queenston to lake Ontario. These 12 feet it is economically impossible to reclaim for power purposes. Of the remaining head, about 20 feet is required to convey the water through the canal.

From the foregoing, it will be seen that the head actually available at the power house under maximum load conditions is 294 feet, which means that 29.6 horsepower is developed for every cubic foot of water per second that flows through the canal. That this is a great forward step in economy is apparent from the fact that only 17.1 horsepower is obtained from each cubic foot of water flowing per second in the most efficient of the three plants previously existing on the Canadian side of the river at Niagara Falls, and 9.5 horsepower in each of the other two; thus every cubic foot of water used in the Queenston power house will now earn about two or three times as much as when it was used at Niagara Falls.

The water of the Niagara river is diverted above the falls and rapids by a special intake structure built in the Niagara river at the mouth of the Welland river at Chippawa. The water thus diverted passes along the deepened and enlarged channel of the Welland river for a distance of 4 miles. It then enters the canal proper, and traverses the Niagara peninsula for a distance of 8¾ miles, passing through an earth section, then into the rock-cut section of the canal through a control gate—an electrically-operated, roller sluice-gate of 48 feet clear span. The canal is 48 feet wide and lined with concrete. The depth of the water is from 35 to 40 feet, and at one point the floor of the canal is more than 140 feet below ground level. The canal terminates in a forebay which is a triangle-shaped enlargement of the canal and is situated near Queenston at the edge of the Niagara gorge.

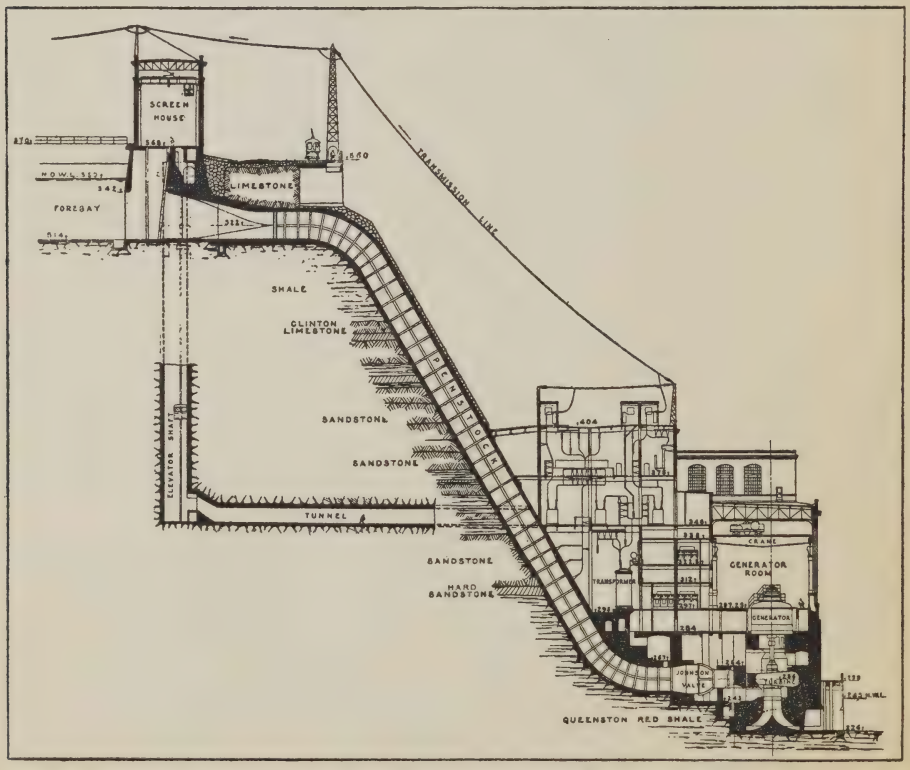
Along the edge of the Niagara gorge, 320 feet above the river surface, is built the screen house. Leaving the forebay the water passes beneath the screen house through wide, screened orifices into the steel penstocks or tubes, 14 to 16 feet in diameter, which lead the water down the face of the cliff to the turbines in the power house.

The power house itself is an immense structure, situated on the edge of the river at the bottom of the gorge. It is about 560 feet long and 180 feet high and if placed in front of the American fall at Niagara would almost hide it. The power house contains nine units of capacities from 55,000 to 63,000 horsepower each under a head of 294 feet at a speed of 187.5 revolutions per minute. The total capacity of the development is 550,000 horsepower.

The turbines are technically described as of the vertical single-runner type and each electrical generator is mounted directly above its own turbine, the rotating parts of each complete unit having a common shaft. The heaviest single integral part of one of these huge units weighs 600,000 lbs. Air is employed for cooling the generators and the warm air issuing therefrom is used in winter to warm the power house.

Three-phase alternating electric current is generated at 12,000 volts, the frequency being 25 cycles per second. Each generator has its own set of switches and transformers, the latter being used to step up the voltage from 12,000 volts to 110,000 volts, and the current is transmitted at 110,000 volts on the Commission's high-tension lines all over south-western Ontario.

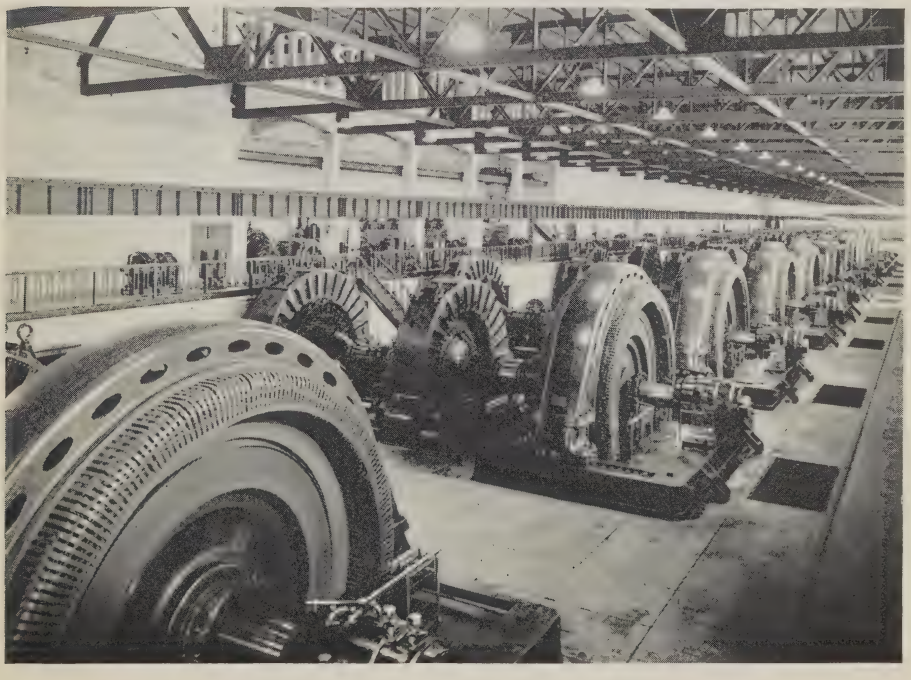
As an engineering feat, the Queenston-Chippawa power development ranks as a work of the first magnitude; in its construction 17,000,000 cubic yards of rock and earth were excavated.



CROSS-SECTION OF QUEENSTON GENERATING STATION

ONTARIO POWER GENERATING STATION

Generating station designed to harmonize with surroundings by blending with cliff behind. View also shows surge tanks, and distributing station above, as seen from Goat Island

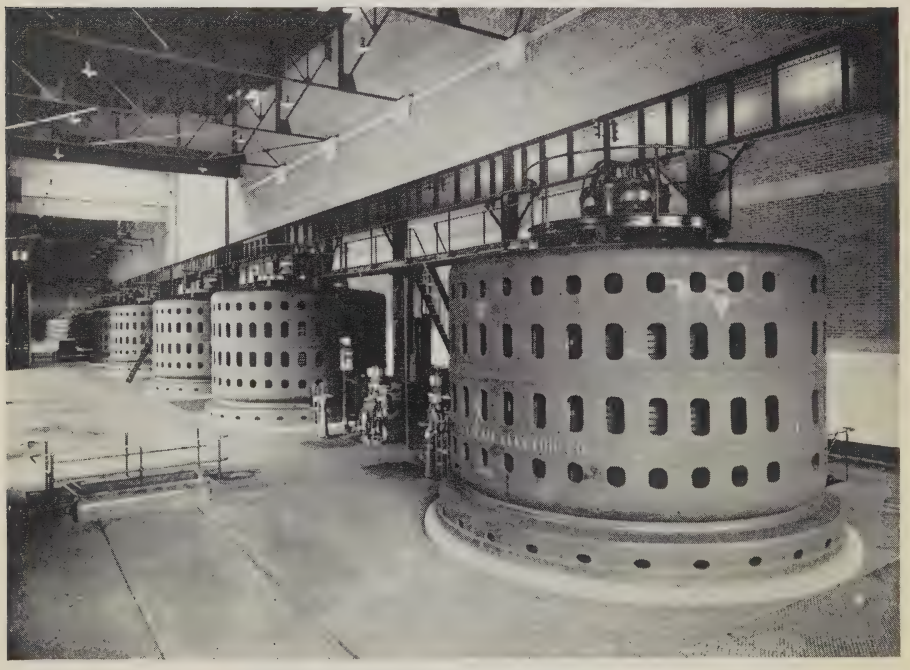


ONTARIO POWER GENERATING STATION

Interior showing horizontal twin turbines and alternators

TORONTO POWER GENERATING STATION

Exterior view of the power house adjacent to the rapids above the Canadian Falls



TORONTO POWER GENERATING STATION

Interior view of the power house showing some of the eleven vertical shaft generators

The rock section of the canal is lined throughout with concrete; not less than 450,000 cubic yards of concrete being used altogether on the whole project. Bridges had to be built to accommodate a number of important railway lines and highways intersected by the canal. Eighty-two miles of construction railway, standard-gauge track, were laid to handle excavated material, and the majority of the locomotives used were electrically driven. Many large shovels, five of them being the largest in the world and electrically operated, were used on this work; each of these five shovels could load a car of 20 cubic yards capacity, standing 60 feet above the shovel, in one and a half minutes.

The work of digging the power canal started in the year 1917 and the opening ceremony took place at Queenston power house in December, 1921; the first unit being placed in commercial use in January, 1922. Additional units were successively installed and placed in service as the growth of load demanded, until, in December, 1925, the plant was brought up to its present capacity by the installation of the ninth unit. The total cost of the development has been about $76,000,000.

It is difficult to convey an appreciation of the enormous power concentrated within the four walls of this great hydro-electric power station. A simple illustration must suffice. Any one of these great generating units will supply the average electrical needs of an industrial city of 200,000 people for electrical energy, to turn the wheels of its factories, to drive its street cars and elevators, to light its streets and business houses, to pump its water, and to supply a superior electrical service to the homes of its citizens.

Ontario Power Generating Station

The generating plant formerly owned by the Ontario Power Company of Niagara Falls, which had been the source of the initial supply of power for the Niagara system in 1910, was in 1917 purchased outright by the Commission on behalf of the municipalities and enlarged to a capacity of 180,000 horsepower. It is situated below the cliff, near the foot of the Horseshoe Falls, and opposite Goat Island. It operates under a head of approximately 180 feet. The water is taken from the river, about a mile above the crest of the Canadian Falls, and is conveyed 6,500 feet through two large conduits, each 18 feet in diameter, one of steel with concrete envelope, the other of reinforced concrete, and a third wood-stave conduit, 13 feet 6 inches in diameter, then through steel penstocks, placed in tunnels passing through solid rock, to the generating station.

The power house contains 15 generating units, the turbines being of the horizontal, double-runner, central-discharge type, direct connected to their respective generators. They have a total capacity of 180,000 horsepower, current being generated at 12,000 volts and transmitted through cables at this voltage to the transformer station at the top of the cliff, where it is stepped up to transmission voltage.

Since acquiring this plant the Commission has made various improvements. For example, with a view to obtaining the maximum power output from the available diversion from the Niagara river, a number of efficiency tests were made on the installed units and it was found that an important gain could be made by replacing the old runners in the turbines of this plant with new runners of lower capacity but of higher efficiency. These were installed as load conditions permitted.

The various buildings and other structures of the Ontario Power development are prominent features of the surroundings of Niagara Falls and occupy portions of the Park Reservation on the Canadian side. They have therefore been designed to harmonize with their surroundings and the company co-operated with the Queen Victoria Niagara Falls Park Commission in furthering the scheme of scenic improvement.

Toronto Power Generating Station

The Commission in 1920 purchased the Toronto Power Company which included the generating plant of its subsidiary the Electrical Development Company, with a capacity of approximately 125,000 horsepower. This plant, now owned by the Ontario municipalities, is operated by the Commission as a unit in conjunction with the other plants to supply power to consumers on the Niagara system.

This plant was designed to utilize only the power obtainable in the immediate vicinity of the Falls; the average effective head developed is 135 feet—less than half that utilized by the Queenston-Chippawa development. One noteworthy feature is that the generating plant is situated close to the intake; another that the development was made on land reclaimed from the river bed itself. The ground upon which the power house now stands was formerly covered with water 8 to 24 feet deep. On the land reclaimed the wheel pit was excavated. It is 416 feet long, 22 feet wide, 150 feet deep, and it is brick-lined; the turbines, which are fed by vertical steel-plate penstocks, are placed near the bottom and the generators at the top; each generator is coupled to its turbine by a long vertical steel shaft supported by a flying arch spanning the wheel-pit.

Water collected from the river by the wing dam passes through submerged arches into the intake and thence down steel penstocks, 10 feet, 6 inches in diameter, to the turbines. After giving up its energy the water passes from the turbines into tunnels paralleling the wheel pit on either side and converging, beneath the lower end of the power house, into the main tailrace tunnel which has its outlet under the river behind the Horseshoe Falls.

Below the power-house floor, in isolated concrete compartments, are placed the oil-switches, power busbars, etc.; the current is transmitted from the power house to a transformer station placed on the crest of the hill overlooking the falls.

The design of the power house building in its classical proportions is striking and impressive. Built of Indiana limestone, it is 467 feet long and 91 feet wide. A magnificent view of the rapids is obtained from the loggia at the northern end.

As in the case of the Ontario Power generating station, the Commission has made certain improvements in the Toronto Power generating station. The old type, high-pressure, oil thrust-bearings on the main generating units have been replaced with modern Kingsbury thrust-bearings. In 1925 extensive repairs were made to the tailrace tunnel which discharges under the Horseshoe Falls and at that time interesting data were obtained relating to the rate of recession of the Falls at the portal of the tunnel which is not far from the point of greatest cliff erosion.

Wasdells Falls Generating Station: The First Hydro-Electric Development Constructed by the Commission

The Wasdells Falls development on the Severn river, one of the plants serving the Georgian Bay system, was the first development constructed by the Commission on behalf of municipalities. Early in 1912 the Commission made a thorough survey of the water powers which were available to serve the district on the east side of lake Simcoe, and recommended to the interested municipalities the development of a site at Wasdells Falls on the Severn river about three miles below lake Couchiching. Work was commenced in July, 1913, and the project was completed in September, 1914. The available head varies from 9 to 12 feet.

The dam substructure and superstructure are constructed of mass and reinforced concrete, and have no special features of design. The two main turbines are of the vertical double-runner type in open-flume settings, and each runner is provided with a separate draft-tube.

The units are designed to operate normally at a speed of 90 revolutions per minute under a head of 12 ft., with a guaranteed capacity, at three-quarters gate, of 600 horsepower. When operating under a 9-ft. head at full gate, the guaranteed capacity is 500 horsepower. The guaranteed efficiencies vary from 75 to 85 per cent. for gate openings of from 50 to 100 per cent. The main generators are of the vertical, 3-phase, 60-cycle type, and each is of 400 kv-a. capacity.

Eugenia Falls Generating Plant: A High-head Development

The second development undertaken by the Commission is also one of the plants serving the Georgian Bay system. It is situated at Eugenia Falls where the Beaver river descends the escarpment near Georgian Bay. Construction was commenced in July, 1914, the initial development was completed in November, 1915, and the plant enlarged to its present capacity in 1919. The unique features of this plant are the arrangements for maximum economic utilization of the run-off from the drainage area, and the high head under which reaction turbines are used.

The development consists essentially of a storage reservoir on the Beaver river with a capacity of 780,000,000 cubic feet created by a dam of the Ambursen type, 51 feet high and 1,900 feet long, situated about half a mile above the Eugenia Falls; a canal 5,000 feet long; a forebay or settling basin; two wood-stave pipes, 46 inches in diameter; surge tanks; steel penstocks 52 inches diameter; and the power house. The gross head under which the plant operates is 552 feet, 50 feet of which is due to that created by the storage dam.

The penstocks supply three spiral-casing, single-runner turbines, two of 2,250-horsepower capacity and one of 4,000-horsepower capacity, at 540 feet head operating at 900 and 720 revolutions per minute respectively. Three-phase, 60-cycle current is generated at 3,800 volts. Based on generator ratings, the electrical capacity of the whole development is 7,500 horsepower.

This development operates in parallel with others of the Georgian Bay system, some of which have lesser storage facilities. During seasons of heavy flow in the various rivers, water is conserved in the Eugenia reservoir, and power for the Georgian Bay system is drawn chiefly from those developments which have lesser storage facilities. During seasons of low water, power is generated by the stored water available at the Eugenia plant. In this way, a greater total amount of electrical energy is developed for the system and a greater minimum capacity is maintained than would be possible if the developments were operated as independent units.

Nipigon River Power Developments: Power Supply for the Development of Natural Resources

At the head of the Great Lakes lies the Thunder Bay system of the Commission embracing the important cities of Port Arthur and Fort William and a tributary district, rich in natural resources. Until recent years development of the territory had been retarded for lack of adequate supplies of power although valuable undeveloped water powers were situated on its streams.

As early as 1901, the city of Port Arthur had embarked in the business of municipal power development by constructing a plant on the Current river. The growing demand for power, however, soon made it necessary to provide for further supply. The results of the activities of the various municipalities in the Niagara district prior to 1906 and the creation of the Hydro-Electric Power Commission, inspired the city officials of Port Arthur to seek a solution of its power problems along lines similar to those adopted by Niagara municipalities.

On behalf of the city of Port Arthur, the Commission purchased power from a power company operating in the district and, later, when this source of supply was beginning to prove inadequate, the municipalities of Fort William and Port Arthur entered into agreements with the Commission for additional power, with the result that the Commission made a thorough canvass of possible new sources of power supply.

The surveys showed that the Nipigon river was the only source of power in sufficiently large quantities to permit the conversion of great supplies of pulpwood into paper at satisfactory costs, and the opening up of the mineral and other resources of the Thunder Bay district. As a result of the final surveys, Cameron Falls was selected as the site for the first development on the river, and construction was started in 1918.*

The Nipigon river is an exceptionally favorable stream for power development. The elevation of lake Nipigon is 850 feet and that of lake Superior 602 feet, giving a fall of 248 feet between the two lakes in a length of about 32 miles along the Nipigon river. Of this fall, about 238 feet can be developed at four main power sites, the upper two of which may possibly be combined by concentrating the head at Pine Portage, where a head of slightly more than 100 feet could be secured. At Cameron Falls, where the first development on the river was made, the head is 78 feet and the head-water level extends about twelve miles back to Pine Portage. About two miles down stream from Cameron Falls at Alexander Landing is the remaining power site, where a head of 60 feet is available. This power site is now being developed.

The discharge from lake Nipigon in a state of nature was remarkably uniform due to the influence of the lake with its area of 1,530 square miles. By the erection of a control dam recently completed at Virgin Falls near the outlet of the lake, the total run-off from the drainage area of 9,125 square miles can be stored in the lake in such a manner as to secure complete regulation of the flow. The regulated flow of 6,500 feet thus secured at Cameron Falls gives, with a 60 per cent load factor, a peak capacity of 75,000 horsepower. The Cameron Falls plant has been completed for this installation with six generating units of 12,500 horsepower each. The corresponding installation at the Alexander development will be 54,000 horsepower. The power is transmitted 70 miles to Fort William and Port Arthur over two transmission lines at 110,000 volts.

Trent River Developments: Operation by Automatic Control

Since the Commission commenced to operate the Central Ontario and Trent system, the increase in the demand for power has necessitated the construction of additional developments on the Trent river. The Trent river is a canalized stream forming part of the inland waterway between Georgian bay and lake Ontario by way of the Kawartha lakes. The navigation dams were constructed several years ago by the Federal Department of Railways and Canals and the various power developments are installed in the neighbourhood of these dams. The first of the new plants is situated at Dam No. 10 or Ranney Falls, near Campbellford. The second and third developments, recently placed in operation, are situated at Dam No. 8 and Dam No. 9 a short distance below the Ranney Falls development.

The Ranney Falls development consists of two units of 5,000 horsepower each, under a head of 47 feet. Dam No. 8 development consists of three units of 2,200-horsepower each, under a head of 32 feet. Dam No. 9 development consists of three units of 1,600 horsepower each, under 22 feet head.

*For fuller discussion of the history of this development and descriptions of the Thunder Bay District, consult *The Nipigon Hydro-Electric Power Development Constructed and Operated for the Municipalities of the Thunder Bay District by the Hydro-Electric Power Commission of Ontario.* 8vo, 40 pp., illus. Toronto, 1922.

The noteworthy feature about the Dam No. 8 and Dam No. 9 developments is the installation of automatic-control equipment to enable the units to be operated from the Ranney Falls station situated about four miles away from the former. The additional attachments to the governors include a solenoid which may be energized or de-energized and a synchronizing motor which records the speed of the units, with the necessary automatic features such as valves, dash-pots, etc., to enable the operations of starting, synchronizing, putting load on the machines, closing the gates and applying the brakes, all to be automatically carried out at the will of the operator at Ranney Falls station.

These plants are unique in the fact that when built they were the largest of the automatic-control type that had been constructed in America. The conclusion to be drawn from the operating experience already secured is that the development of many power sites which would otherwise be commercially impracticable will probably be brought within the range of economic feasibility due to the saving in operating costs that can be effected by the use of automatic-control equipment.

Other Power Developments Made by the Commission

Several other hydro-electric developments have been constructed by the Commission and some, acquired by purchase, have been enlarged or improved. The Commission has also created additional storage and provided regulating dams upon various rivers tributary to those upon which its power developments are situated.

Purchased Power

Beginning with the Ontario Power Company contract in 1908, from time to time, as found advisable in the interests of the municipalities, the Commission has made contracts with a number of companies for the supply of various amounts of electrical power for its several systems. Furthermore, with various other producers of electrical energy, it has made arrangements for the interchange of power. Power for the Ottawa and the St. Lawrence systems is purchased, as also are portions of the power used on the Niagara system, on the Central Ontario and Trent system, and on the Rideau system. On the Georgian Bay system, under reciprocal arrangements, surplus power is exchanged with, or purchased from, the Orillia Water, Light and Power Commission.

Pending the removal of certain difficulties at present preventing the construction by the Commission of new large developments on the international portion of the St. Lawrence river and on the Ottawa river, which latter is an interprovincial stream, a supply of power has been arranged for by contract with the Gatineau Power Company which has recently constructed developments in Quebec on the Gatineau river, a chief tributary of the Ottawa river. The contracts with this company provide for an ultimate delivery of 260,000 horsepower of 25-cycle power, and up to 100,000 horsepower of 60-cycle power. The 25-cycle power is received at the interprovincial boundary on the Ottawa river, and conveyed over a new 220,000-volt transmission line terminating in Toronto. It releases an increased amount of Niagara power for use in the more westerly portions of the Niagara system. The 60-cycle power, conveyed over 110,000-volt lines, will take care of the requirements of Eastern Ontario.

* * *

The Hydro-Electric Power Commission has aimed to have its physical properties express the best features of engineering design and practice. Engineers familiar with similar achievements in other countries, who have visited the works of the Commission, have highly commended the manner in which the widely-varying conditions have been dealt with in Ontario. The foregoing very brief description of the more important power developments operated by the Commission is presented in order that some general conception may be formed respecting the ways and means by which the water-power resources of Ontario are harnessed for the benefit of the citizens of the Province.